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**AN APPROXIMATE SHADOWING TECHNIQUE
TO AUGMENT THE AERODYNAMIC TORQUE MODEL
IN THE AE-C MULTI-SATELLITE
ATTITUDE PREDICTION
AND CONTROL PROGRAM (MSAP/AE)**

NOVEMBER 1974

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COMPUTER SCIENCES CORPORATION

AN APPROXIMATE SHADOWING TECHNIQUE TO AUGMENT
THE AERODYNAMIC TORQUE MODEL IN THE AE-C
MULTI-SATELLITE ATTITUDE PREDICTION
AND CONTROL PROGRAM (MSAP/AE)

Prepared by

COMPUTER SCIENCES CORPORATION

For

GODDARD SPACE FLIGHT CENTER

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Prepared by:

D. M. Gottlieb 10/14/74
D. M. Gottlieb Date

Approved by:

M. Joseph 10/14/74
M. Joseph Date
Technical Supervisor

C. M. Gray 10/14/74
C. M. Gray Date

R. D. Cardwell 10/20/74
R. D. Cardwell Date
Technical Area Manager

S. G. Hoovy 10/14/74
S. G. Hoovy Date

ABSTRACT

This document presents the mathematical basis and unit descriptions for subroutines AEROM and SHADOW. For the most part, these subroutines make up the aerodynamic torque calculation of MSAP/AE. An overview and a description of both satellite-independent and satellite-dependent code are given.

Cross-referenced listings of subroutines AEROM and SHADOW are included as an Appendix.

Further details on the MSAP/AE system may be found in the MSAP/AE System Description (Reference 1).

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SECTION 1 - INTRODUCTION

1.1 ORIGIN OF SHADOW MODEL

For spacecraft with perigees below approximately 200 km, aerodynamic torques may substantially affect the attitude and the magnitude of the angular momentum. In the case of Atmospheric Explorer-C (AE-C) operation at a perigee altitude of 140 km produces attitude shifts up to nearly 1 degree/orbit and angular momentum changes of up to 10 in-lb-secs/orbit. Since attitude constraints allow only a 2-degree deviation in the spin axis from orbit normal, the aerodynamic torques must be accurately known for predictive purposes.

The version of the MSAP/AE aerodynamic torque model in use prior to the development of the shadowing model had several major shortcomings:

1. It was a one-component model, excluding all appendages. Investigation showed the protuberances to be the major source of aerodynamic torques.
2. It neglected all shadowing.
3. It treated the case of the spinning spacecraft as a series of instantaneous torques. This method is highly suspect when the sampling interval used is not sufficiently small compared to the spin period of the spacecraft.
4. It assumes pure adsorption/reemission as opposed to reflection.
5. In the standard mode of operation, no allowance is made for varying atmospheric densities caused by solar activity or other effects. There is provision in the program, however, for use of a 10.7-c.m. solar activity index in scaling the atmospheric model.

1.2 MODEL SPECIFICATIONS

The shadowing model addresses the problem areas described above as follows:

1. The spacecraft decomposition into components for the purpose of calculating aerodynamic torques is increased to include several major appendages, specifically the adapter ring and Solar Pointing Subsystem (SPS) on the "top" of the main body, and the rotating mirror and the two rectangular boxes on the "bottom" of the main body. Other appendages are not considered because either their areas are negligibly small (as for the antennas), or the coding necessary to account for them would be too complex (as for a small box on the side of the major cylinder on the +y-axis).
2. Shadowing of one component by other components is taken into account by a model which treats the various components as equivalent cylinders. All shadows thrown by each component are calculated, and equivalent negative-area elements are added to the spacecraft decomposition.
3. The spinning spacecraft is taken into account by using formulas derived by averaging the torques in an inertial coordinate system over the full 360-degree range of wind azimuth angle. The SPS is also treated by a similar formula technique when it is "off" (i.e., spinning with the spacecraft). When the SPS is "on" (i.e., inertially fixed), it is treated as a separate component.
4. The adsorption/re-emission-versus-reflection question is not addressed.
5. The variation-in-atmospheric-density problem is not considered.

1.3 SHADOWING MODEL IN MSAP/AE

In MSAP/AE, subroutine TORQUE acts as the driver for all torque calculations. To obtain the aerodynamic torque, TORQUE calls subroutine AEROM, providing it with the necessary input data and accepting from it the instantaneous torques in the body coordinate system.

In the previous version of MSAP/AE, AEROM performed a simple one-component calculation of the aerodynamic torque and returned the results to TORQUE. In the shadowing model, AEROM calls subroutine SHADOW to obtain the shadowed elements, and then calculates the aerodynamic torque from the total spacecraft decomposition. Values of the aerodynamic torque are returned by AEROM to TORQUE in exactly the same manner as was done previously.

The design of the shadowing model was accomplished with minimal impact on MSAP/AE routines other than AEROM. The only modifications to subroutine TORQUE are to calculate the SPS on/off flag, and the wind and Sun vectors in body coordinates. These are required by AEROM and SHADOW. As a result, the AEROM/SHADOW package is easily adaptable to other uses.

1.4 DOCUMENT SCOPE

This document is intended to be used in two ways:

1. AE-C spacecraft support tasks may use it to understand and document attitude predictions made by MSAP/AE.
2. Future spacecraft support tasks may use it to assist in writing similar aerodynamic torque routines for other spacecraft or in modifying the AEROM/SHADOW package.
3. Details of the modifications to the MSAP/AE system required to incorporate AEROM/SHADOW are available in Reference 2, and are not specifically included in this document.

1.5 RECOMMENDATION FOR FUTURE DEVELOPMENT

The current aerodynamic torque model in MSAP should be readily extendable to AE-D, AE-E, and possibly other similar spacecraft. Only minor modifications should be needed to adapt it to AE-D and AE-E. A few improvements in the model can be made which would be of value to at least these two spacecraft.

1. The effect of the Earth's rotation should be taken into account in the wind velocity. This is approximately a 10 percent effect.
2. The variation of atmospheric density with solar activity should be investigated. Some coding is already present in MSAP, but it is not activated because solar activity measures are not input. The most appropriate of these measures should be selected and incorporated into MSAP.

There are several assumptions made by the current model whose validity may be questionable or conditions different from those experienced by the AE missions. These are:

1. The current model assumes pure adsorption/re-emission as opposed to reflection. There is no provision for evaluating the fractional reflection, nor for computing its effect.
2. Spacecraft flying below about 125 km will be clearly out of the free flow regime. The current model only treats free flow, as any other assumption leads to great complexity. The degree to which this assumption holds can be calculated, but is not presented here.
3. The current model forces a fairly straightforward "building block" approach on the spacecraft decomposition. Specifically, only a "cylinder on a cylinder" configuration is allowed.

While the current model could provide a structure on which to build a more complex aerodynamic torque model, it is recommended that consideration be given to different approaches at such time as the program is evaluated for generalization to future missions.

Since any truly general model will be very complex, it may be prohibitively expensive, in terms of core or execution time, to incorporate it into a system. In light of this problem, a pre-calculated torque approach seems promising. Here, the torque is calculated ahead of time as a function of the relevant variables. Tables or formulas are then supplied to the master program.

In summary, there are a few modifications to existing routines which will be useful for AE-D, AE-E, and similar spacecraft. It is further recommended that a study be made of the problem of the best approach to use for the development of a more general model.

SECTION 2 - DESCRIPTION OF SUBROUTINE AEROM

2.1 MATHEMATICAL DEVELOPMENT

Subroutine AEROM provides the control structure for the calculation of aerodynamic torques. In addition, it contains the logic which determines program flow where that flow depends on the spacecraft status.

AEROM computes aerodynamic torques based on a component model implemented in subroutine SHADOW. Shadowing is taken into account by adding in negative-area shadow elements computed by SHADOW. All internal calculations are done in cgs units, except that linear dimensions and areas are in inches and square inches, respectively. The torques, converted to cgs units, are calculated in an instantaneous body coordinate system and are passed out to subroutine TORQUE.

2.1.1 Calculation of Wind and Sun Angles

AEROM computes the wind and Sun angle azimuths and elevations for use by itself and by SHADOW.

The following wind angles are calculated from the wind unit vector in instantaneous body coordinates:

$$\alpha_w = \tan^{-1}(w_y/w_x)$$

$$\beta_w = \sin^{-1}(w_z)$$

where α_w and β_w are the wind azimuth and elevation angles (respectively, relative to the body frame) and $w = (w_x, w_y, w_z)$ is the wind unit vector in the body frame.

The Sun azimuth is defined as the dihedral angle measured from the wind, z-axis plane to the Sun, z-axis plane. The Sun elevation is defined as the angle of the Sun vector above the body x,y plane:

$$\alpha_s = \tan^{-1} (s_y / s_x) - \alpha_w$$

$$\beta_s = \sin^{-1} (s_z)$$

where α_s and β_s are the Sun azimuth and elevation angles, respectively, and $s = (s_x, s_y, s_z)$ is the Sun unit vector in the body frame.

The Sun azimuth is converted into an angle between 0 and 90 degrees to accommodate formulas used below, and IYFLAG is defined in Table 2-1.

2.1.2 Computation of Aerodynamic Torques

The method of computation for the aerodynamic torques depends on the spacecraft state.

If the spacecraft is spinning, and if the SPS is turned off, the torques are computed via the following formulas. The formulas were generated in an inertial coordinate system by averaging over the full 360-degree range of wind azimuth. They were then converted to the instantaneous body system in order to accommodate subroutine TORQUE. The formulas for the torques are

$$\Gamma_x = -C \sin(\alpha_w) \Gamma_2$$

$$\Gamma_y = C \cos(\alpha_w) \Gamma_2$$

$$\Gamma_z = 0$$

Table 2-1. Modification of Sun-Wind Azimuth Angle and y Offset Flag

ORIGINAL α_s BETWEEN	FINAL α_s	IYFLAG
$0^\circ - 90^\circ$	α_s	+1
$90^\circ - 180^\circ$	$180^\circ - \alpha_s$	+1
$180^\circ - 270^\circ$	$\alpha_s - 180^\circ$	-1
$270^\circ - 360^\circ$	$360^\circ - \alpha_s$	-1

where

$$\Gamma_2 = -436.0 + 8.0 \beta_w - 11.0 \beta_w^2 - 2505.0 \Delta Z + \Gamma_{SPS}$$

$$C = 8.19 C_D \rho V^2$$

$$\Gamma_{SPS} = \begin{cases} 1513.0 & , \text{ for } \beta_w \geq 0^\circ \\ 1513.0 + 77.0 \beta_w & , \text{ for } \beta_w < 0^\circ \end{cases}$$

In the above equations

α_w = wind azimuth (degrees)

β_w = wind elevation (degrees)

ΔZ = Z-component of vector from geometric center of spacecraft to its center of mass (inches)

C_D = drag coefficient

ρ = atmospheric density (gm/cm^3)

V = wind velocity (cm/sec)

$\vec{\Gamma} = (\Gamma_x, \Gamma_y, \Gamma_z) = \text{torque (cgs units)}$

If the spacecraft is spinning and the SPS is turned on, the torques are calculated partially by formulas (formula for Γ_2 used with $\Gamma_{SPS} = 0$) and partially by computations of the SPS-related elements as for the despun case below.

If the spacecraft is despun, the torques are computed by

$$\vec{\Gamma} = \sum_{i=1}^N 8.19 C_D \rho V^2 A_i (\vec{r}_i \times \hat{w})$$

where $\vec{\Gamma}$ = torque (cgs units)

C_D = drag coefficient

ρ = atmospheric density (gm/cm^3)

V = wind velocity (cm/sec)

r_i = vector from spacecraft center of mass to ith element's geometric center (inches)

\hat{w} = wind unit vector in B.G. coordinates

$$A_i' = \begin{cases} A_i' (-\hat{n}_i \cdot \hat{w}) & , \text{ if ith element is a plate} \\ A_i' / 4.0 & , \text{ if ith element is a sphere} \\ A_i' [1 - (\hat{n}_i \cdot \hat{w})]^{1/2} & , \text{ if ith element is a cylinder} \end{cases}$$

\hat{n}_i = unit vector normal--ith element if it is a plate, or unit vector along axis of ith element if it is a cylinder

A_i' = surface area of ith element if it is a plate (one side) or sphere, and height x diameter if it is a cylinder

N = number of elements

If the SPS is off, its parameters are evaluated by subroutine SHADOW.

2.2 AEROM UNIT DESCRIPTION

Language

FORTRAN IV

Functional Description

Subroutine AEROM calculates the aerodynamic torques on the AE-C spacecraft in the instantaneous body coordinate system.

Calling Sequence

Subroutine AEROM is entered through the following FORTRAN statement:

CALL AEROM (WIND, TORQUE)

The arguments in the calling sequence are listed below:

<u>Argument</u>	<u>Name</u>	<u>Symbol</u>	<u>I/O</u>	<u>Definition</u>	<u>Units</u>	<u>Format</u>	<u>Dimension</u>
WIND	W		I	Wind unit vector in body coordinates	None	R*4	3
TORQUE	\bar{F}		O	Torque vector in body coordinates	$\text{cm}^2 \cdot \text{gm/sec}^2$	R*4	3

External References

SHADOW, TABLE

COMMON Variables Used by SHADOW

<u>COMMON Name</u>	<u>Variable Name</u>	<u>I/O</u>
AEROBD	NCOMPS	I
	AREA(30)	I
	RV(3, 30)	I
	ANV(30)	I
	ITYPE(30)	I
SPSFLG	ISPSON	I
	MSPFLG	I
	SUN(3)	I
	XYZCOM(3)	I
CONSTS	RTD	I
	PI	I
	HALFPI	I
	TWOPI	I
GAERO	RHO	I
DSRNS	IDUMP	I
ADRAGC	CD	I

<u>COMMON Name</u>	<u>Variable Name</u>	<u>I/O</u>
INTOUT	INTOUT(100)	I
ORBIT	VMAG	I
	HGHT	I

Method

See Section 2.1.

NAMELIST Inputs

None

Other Input/Output Information

Subroutine AEROM can produce diagnostic printout if INTOUT(20) \neq 0 .

Progressively more output is generated by INTOUT(20) = 1, 2, 4, or 8 .

Constraints, Error Conditions, and Recovery

The wind elevation angle, β_w , should satisfy the equation:

$$|\beta_w| \leq 3.5^\circ$$

SECTION 3 - DESCRIPTION OF SUBROUTINE SHADOW

3.1 MATHEMATICAL DEVELOPMENT

Subroutine SHADOW is designed to supplement subroutine AEROM in the calculation of aerodynamic torques. AEROM accepts a set of input elements¹ (plates, spheres, or cylinders) from which it calculates the aerodynamic torque. SHADOW (called by AEROM) allows for shadowing by expanding the list of elements to include elements of negative area. These negative areas exactly cancel the torque which would have been incorrectly computed in AEROM assuming no shadowing of, or by, the element.

SHADOW accepts input of any number of elements, but can do shadowing only on contiguous cylindrical components. Each such component must be closed at both ends by a circular plate, or by virtue of its resting on another component. Figure 3-1 shows a sample configuration. Current array sizes require a 30-element limit after shadow elements are added.

To make use of the modeling features of subroutine SHADOW, the major components on AE-C have been represented as equivalent cylinders. The main body is nearly cylindrical and its approximation by a cylinder is valid. This is also true of the adapter ring and the mirror (since it is spinning very rapidly). The PSB and x-box (defined below) are considered to be cylinders for the purpose of shadowing, but their areas are calculated from their true geometry. The SPS presents a variety of shapes, depending on the position of the Sun. It is converted to a cylinder having an area equal to the area projected into the wind for the current Sun position. Its height is obtained in a similar manner, and its radius obtained from the area and the height.

¹ By "element," a single plate, sphere, or (open-ended) cylinder is intended. By "component," a small group of elements comprising a geometric unit is intended, such as a cylinder plus its end plates.

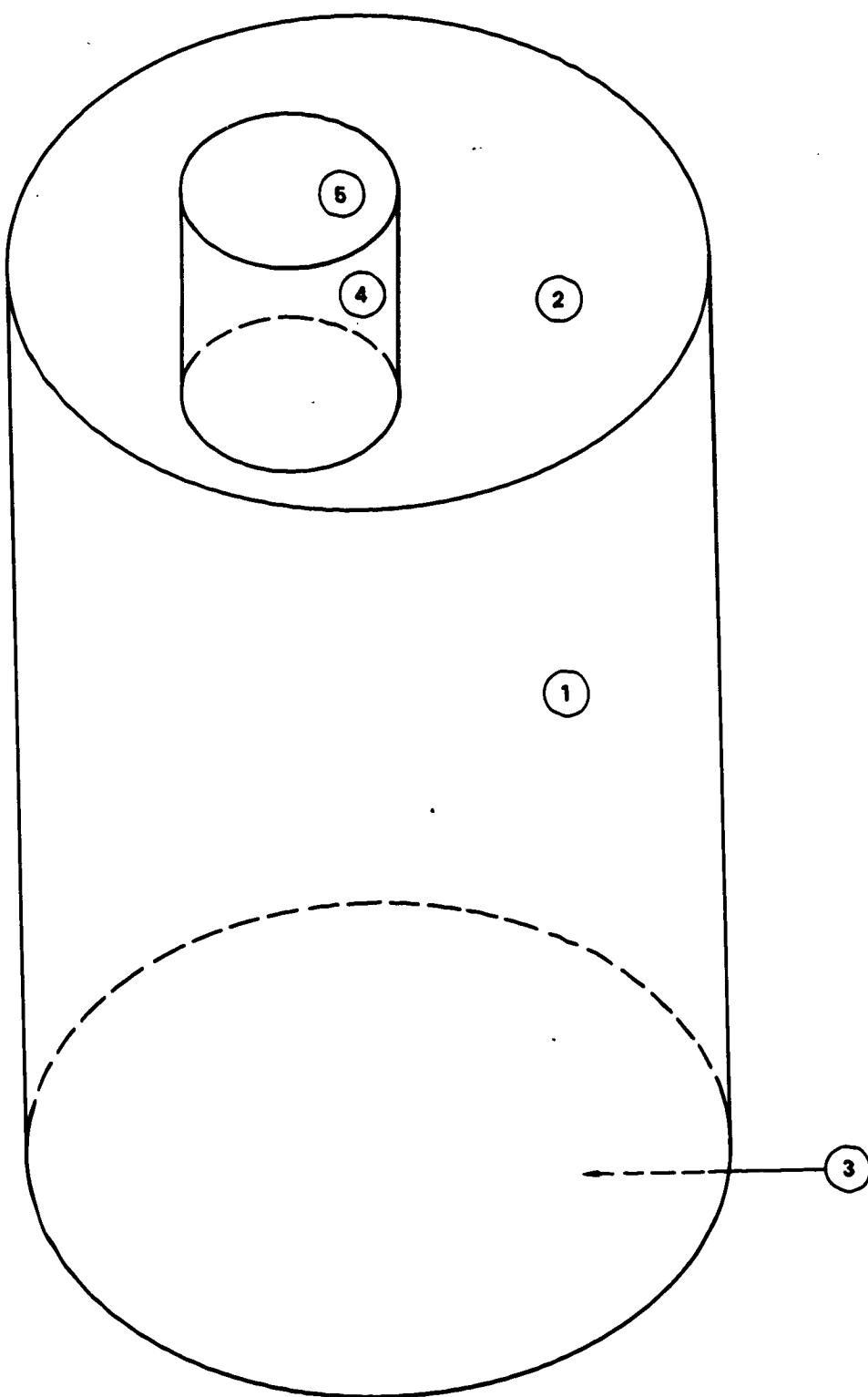


Figure 3-1. Sample Configuration of a Cylinder on a Cylinder

SHADOW is a self-contained subroutine, called only by AEROM and reporting only to AEROM. Its sole function is to add elements to the spacecraft decomposition in order to approximate shadowing. The user may, however, add coding to SHADOW to modify the specifications of his original elements.

Several simplifications have been incorporated in the model. These restrict the range of wind angles over which SHADOW will work accurately. Specifically, wind elevations of absolute value > 3.5 degrees will cause errors in calculating the shadow elements. Since formulas involving the wind elevation are used frequently, and since these formulas are valid only within their range of definition ($-3.5 \leq \beta_w \leq 3.5$), the aerodynamic torque model should be turned off completely whenever it is expected that this constraint will be violated.

3.1.1 Original Spacecraft Decomposition

The spacecraft decomposition into elements for the purpose of calculating aerodynamic torques resulted in 13 elements. Each element is fully described by the parameters given in Table 3-1.

Some items to note about Table 3-1 are

- All elements are either circular plates or cylinders for the purpose of shadowing.
- PARA and PARB are used only for shadowing purposes and do not affect AREA.
- Because each element has only one value for IFSHLD, it may be shadowed by only one element unless special coding is introduced (Section 3.1.5)
- All plates are circular for the purposes of shadowing.

Often, the element specifications depend on the spacecraft attitude, Sun position, etc. The parameters describing the spacecraft status are listed in Table 3-2 and illustrated in Figure 3-2.

Table 3-1. Component Parameters

NAME	SYMBOL	DEFINITION
AREA	A	MAXIMUM PROJECTED AREA OF ELEMENT
RV	\hat{R}	VECTOR FROM GEOMETRIC CENTER OF SPACECRAFT TO GEOMETRIC CENTER OF ELEMENT
ANV	\hat{n}	UNIT VECTOR NORMAL TO PLANAR ELEMENTS (OUTWARD DIRECTION) AND ALONG AXIS OF SYMMETRY FOR CYLINDRICAL ELEMENTS
PARA	r	RADIUS OF ELEMENT
PARB	h	HEIGHT OF ELEMENT (FOR CYLINDRICAL ELEMENTS)
ITYPE		TYPE OF ELEMENT <ul style="list-style-type: none"> = 0, CIRCULAR PLATE = 1, SPHERE (NO SHADOWING) = 2, CYLINDER
IFSHLD		SHADOWING FLAG <ul style="list-style-type: none"> = 0, NO SHADOWING OF THIS ELEMENT = 50, ELEMENT SHADOWED IF WIND HAS ANY COMPONENT IN SAME DIRECTION AS \hat{n} = 100 + Δ, (FOR PLATES ONLY) SHADOWING OF PLATE BY ELEMENT NUMBER Δ, WHICH MUST BE A CYLINDER = 200 + Δ, (FOR CYLINDERS ONLY) SHADOWING OF CYLINDER BY ELEMENT NUMBER Δ, WHICH MUST BE A PLATE

Table 3-2. Spacecraft State Parameters

NAME	SYMBOL	DEFINITION
ISPSON		SPS FLAG = 0, OFF = 1, ON
MSPFLG		SPACECRAFT SPIN FLAG = 0, DESPUN = 1, SPINNING
WIND	\hat{w}	WIND UNIT VECTOR - DEFINED BY AN OUTWARD POINTING VECTOR STARTING AT ORIGIN (INSTANTANEOUS BODY COORDINATES)
SUN	\hat{s}	SUN UNIT VECTOR - DEFINED BY AN OUTWARD POINTING VECTOR STARTING AT ORIGIN (INSTANTANEOUS BODY COORDINATES)
<hr/>		
DERIVED PARAMETERS		
ALPHA	α_w	WIND AZIMUTH - RELATIVE TO BODY x, z PLANE
BETA	β_w	WIND ELEVATION - ABOVE BODY x, y PLANE
SUNAZI	α_s	SUN AZIMUTH - DEFINED AS DIHEDRAL ANGLE MEASURED FROM WIND, z-AXIS PLANE TO SUN, z-AXIS PLANE
SUNELE	β_s	SUN ELEVATION - ABOVE BODY x, y PLANE

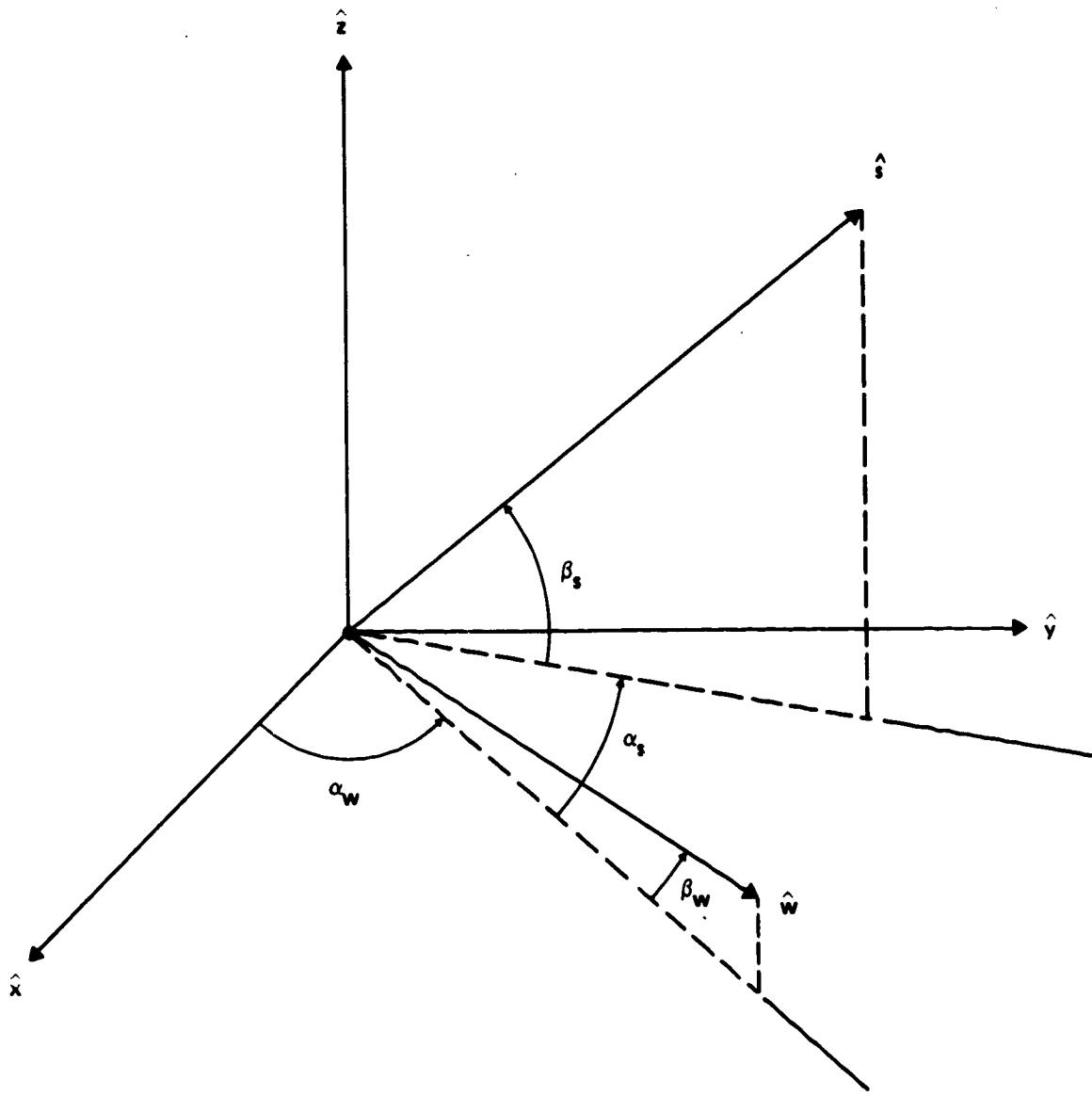


Figure 3-2. Sun and Wind Vector Orientation

The basic AE-C spacecraft decomposition is given in Table 3-3 and illustrated in functional form in Figures 3-3 and 3-4.

The elements in Table 3-3 represent seven components. These are

- Main cylinder
- Adapter ring mounted on the top plate of the main cylinder
- Solar pointing subsystem (SPS) mounted within the adapter ring and extending above it
- Rotating mirror on the bottom plate of the main cylinder
- Pressure sensor B (PSB) box on the bottom plate of the main cylinder in the direction of the negative y-axis
- Box housing the cylindrical electrostatic probe on the bottom plate of the main cylinder in the direction of the positive x-axis ("x-box")

3.1.2 Initialization (Segment 1)

SHADOW performs computations in six segments:

1. Initialization
2. Alteration of original elements
3. Creation of shadowing elements
4. Alteration of shadowing elements
5. Calculation of cylindrical offsets
6. Output

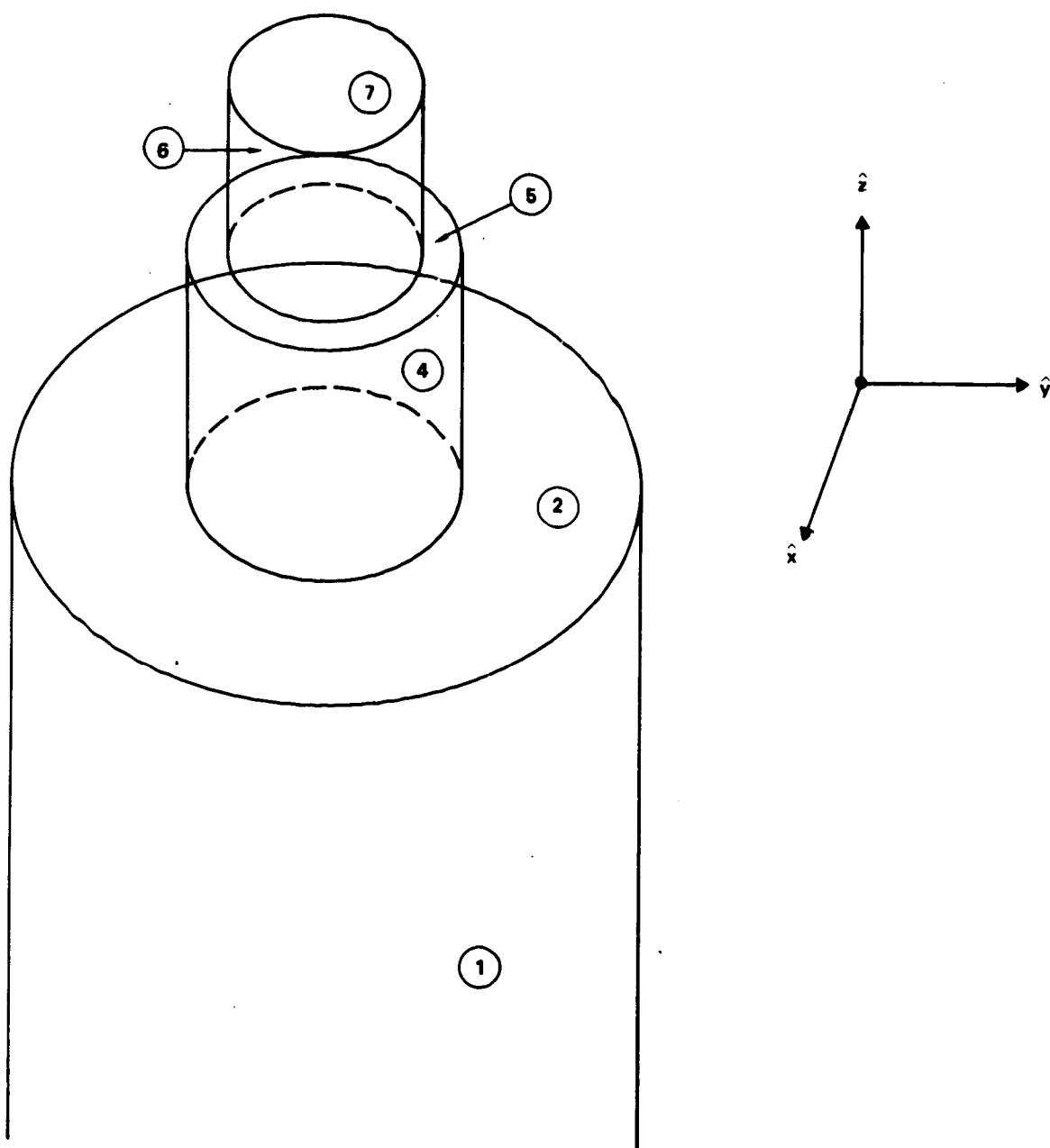
Segments 2, 4, and to some extent 1, are very satellite dependent, as they involve modification of element specifications due to the current spacecraft state. Segments 3 and 5 are entirely satellite independent, subject to the wind elevation discussed below. Segment 1 is executed only once, namely, the first time SHADOW is called. Various parameters describing the original elements are stored at this time. They are subsequently altered, but are returned to their original values each time SHADOW is called.

Table 3-3. AE-C Decomposition Elements

NUMBER	TYPE	DESCRIPTION	AREA (SQ. INCHES)	\hat{h}	\bar{R} (INCHES)	r' (INCHES)	h (INCHES)	IFSHLD
1	2 ⁺	MAIN BODY	2385.0	0, 0, 1	0, 0, 0, 0, 0	26.5	45.0	0
2	0	MAIN BODY TOP	2206.2	0, 0, 1	0, 0, 0, 22.5	26.5		104
3	0	MAIN BODY BOTTOM	2206.2	0, 0, -1	0, 0, 0, -22.5	26.5		108
4	2 ⁺	ADAPTER RING	25.5	0, 0, 1	0, 0, 0, 23.25	8.5	1.5	202
5	0	ADAPTER RING TOP	277.0	0, 0, 1	0, 0, 0, 24.0	8.5		106
6	2 ⁺	SPS	56.3*	0, 0, 1	0, 0, 0, 26.0*	6.0*		205
7	0	SPS TOP	50.3*	0, 0, 1	0, 0, 0, 28.0*	6.0*		50
8	2 ⁺	MIRROR	22.5	0, 0, -1	0, 0, 0, -25.65	1.785	6.3	203
9	0	MIRROR TOP	10.0	0, 0, -1	0, 0, 0, -28.8	1.785		50
10	2 ⁺	PSB	14.1*	0, 0, -1	0, 0, -24.0, -24.0	2.45*	3.0	203
11	0	PSB TOP	14.1	0, 0, -1	0, 0, -24.0, -25.5	2.12*		50
12	2 ⁺	x-BOX	10.3*	0, 0, -1	7.0, 0, 0, -23.28	2.10*	1.56	203
13	0	x-BOX TOP	10.3	0, 0, -1	7.0, 0, 0, -24.06	1.8*		50

+THE R_x AND R_y VALUES OF THESE ELEMENTS ARE ALTERED ACCORDING TO SPACECRAFT STATUS PARAMETERS (SEE SECTION 2.5).

*THESE VALUES ARE ALTERED ACCORDING TO SPACECRAFT STATUS PARAMETERS (SEE SECTION 2.2).



**Figure 3-3. Representation of Elements on Top Plate
of Main Cylinder of AE-C**

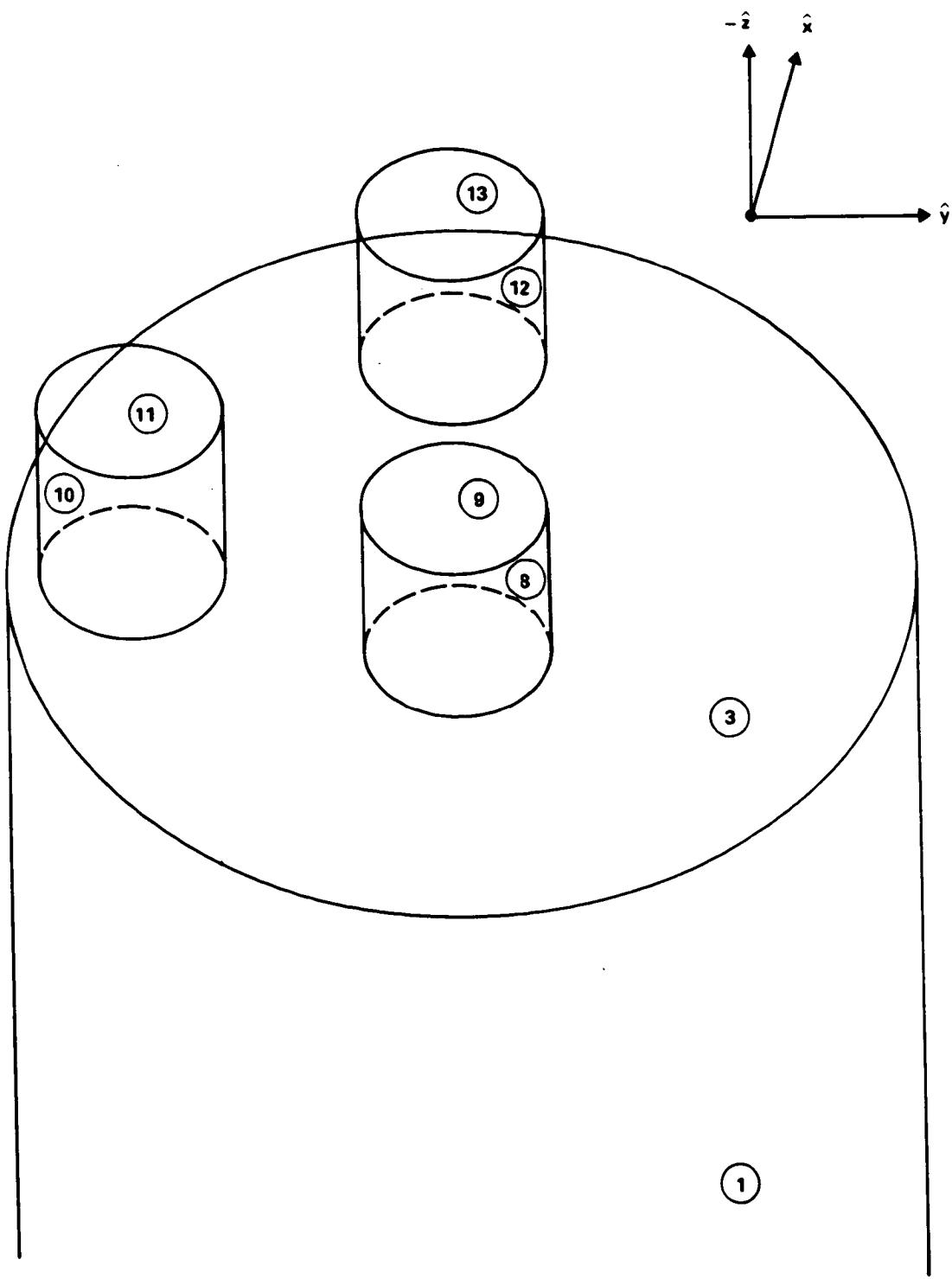


Figure 3-4. Representation of Elements on Bottom Plate
of Main Cylinder of AE-C

3.1.3 Alteration of Original Elements (Segment 2)

The specifications describing the elements in the original spacecraft decomposition must, in some cases, be altered within SHADOW to accommodate changing spacecraft status parameters.

Segment 2 alters the initial decomposition as follows:

- For each element the x, y, and z components of the center of mass (c. m.) offset (defined as the vector from the spacecraft geometric reference center to the c. m.) are subtracted from \vec{R} (defined as the vector from the spacecraft geometric reference center to the geometric center of the element).
- The PSB and x-box are rectangular boxes whose projected areas are a function of wind azimuth. For a box located with faces perpendicular to the x- and y-axes, and lengths of ℓ_x and ℓ_y , respectively, the projected area (exclusive of wind elevation effects) is given by

$$A_p = 2 \text{ hr}$$

where $r = \frac{1}{2}(\ell_x |\cos \alpha_w| + \ell_y |\sin \alpha_w|)$
 h = height of box

α_w = wind azimuth

Now r and h are the radius and height of the equivalent cylinder used for shadowing.

The PSB has $\ell_x = 3.0$ inches and $\ell_y = 4.7$ inches, and the x-box has $\ell_x = 2.57$ inches and $\ell_y = 4.04$ inches.

- When operational, the SPS tracks the Sun. Since it physically moves relative to the spacecraft, its area and \vec{R} are dependent

on the Sun azimuth (α_s) relative to the wind, and elevation (β_s) relative to the spacecraft x,y plane. The values of R_z , and the component of R projected into the body x,y plane (R_{xy}) were determined experimentally by constructing a physical model of the SPS.

A shadow of the model SPS was projected onto a screen and its outline traced as a function of Sun elevation and azimuth. The tracings were measured using an area and moment integrating planimeter to obtain areas and xy and z offsets.

The experimental data points were fit to curves by a least-squares multiple regression technique using fitting parameters designed to avoid CPU-costly trigonometric functions. The resultant formulas are

$$\begin{aligned} \text{Area} = & 55.3549 - 0.3964 |\beta_s - 45| - 0.002909 \alpha_s^2 + 369.36/(\alpha_s + 30) \\ & + 0.2014 \alpha/(\beta_s + 2) + 0.006539 \alpha |\beta_s - 45| - 0.003889 (\beta_s - 45)^2 \\ & - 0.1518 |\alpha_s - 45| - 0.04 |\beta_s - \alpha_s| + 5.9626 \sin(\beta_s/57.296) \text{ sq. inches} \end{aligned}$$

$$R_z = 26.8005 - 0.02464 |\beta_s - 45| - 0.008606 \alpha + 0.0002 \alpha |\beta_s - 45| \text{ inches}$$

$$\begin{aligned} R_{xy} = & \left[0.9729 - 0.006717 |\beta_s - 45| - 0.01118 \beta_s - 12.8741/(\alpha_s + 30) \right. \\ & - 9.225 \times 10^{-5} (\alpha_s - 45)^2 + 0.001056 |\beta_s - \alpha_s| \\ & \left. + 8.984 \times 10^{-5} (\beta_s - \alpha_s)^2 \right] (\text{IYFLAG}) \text{ inches} \end{aligned}$$

where IYFLAG is discussed below, and α_s and β_s are in degrees, subject to the constraints

$$0^\circ \geq \alpha_s \geq 90^\circ$$

$$0^\circ > \beta_s \geq 90^\circ$$

In practice, $\beta_s \geq 80^\circ$ is prohibited by the hardware.

The Sun elevation can never be negative since this would mean the Sun was "set" and the SPS automatically turned off. Because of geometric symmetry of the SPS at various Sun-wind angles, the Sun-wind azimuth was converted in AEROM to an angle between 0 and 90 degrees and the IYFLAG set from Table 2-1.

The function of IYFLAG is to change the sign of R_{xy} as the original α_s exceeds 180 degrees. The large number of parameters in the equation are to provide accuracy, as the SPS is a major contributor to the net torque.

For purposes of shadowing, the SPS is also converted into an equivalent cylinder of height PARB(6) and radius PARA(6) by assuming

$$\text{PARB}(6) = h = 2(R_z - 24.0)$$

$$\text{PARA}(6) = r = \text{Area}/2h$$

Mean errors in the Area, R_{xy} , and R_z parameters caused by errors in measurement and curve fitting are estimated as

Error in Area = 1 sq. inch

Error in R_{xy} = 0.2 inch

Error in R_z = 0.15 inch

If the SPS is turned off, it is assumed to be co-rotating with the spacecraft and is assigned the following parameters:

$$\text{Area} = 48.0 \text{ sq. inches}$$

$$\vec{R} = 0.0, 0.0, 26.07 \text{ inches}$$

$$\hat{n} = 0.0, 0.0, 1.0 \text{ inch}$$

$$r = 6.0 \text{ inches}$$

$$h' = 4.0 \text{ inches}$$

3.1.4 Creation of Shadowing Elements (Segment 3)

This segment is essentially satellite independent. All shadowing is approximated by a cylinder resting on a plate (Figure 3-5). If the wind is from "below," the plate shadows the cylinder; if it is from "above," the cylinder shadows the plate.

The technique used to allow for shadowing is to add elements with negative areas representing the shadowed region.

3.1.4.1 Shadowing of Cylinder by Plate

In this case, the plate throws a shadow onto the cylinder, shadowing all or some portion of the bottom of the cylinder. The height to which the shadow rises is approximated by (Figure 3-6):

$$h^* = (d - r_c) \cdot |\tan \beta_w|$$

where r_c = radius of cylinder

β_w = elevation angle of wind

$$d = \sqrt{(x_3 - x_c)^2 + (y_3 - y_c)^2}$$

where (x_c, y_c) = intersection of cylinder axis and circular plate

(x_3, y_3) = intersection point of edge of circular plate and a line through (x_c, y_c) with slope $= \tan \alpha_w$

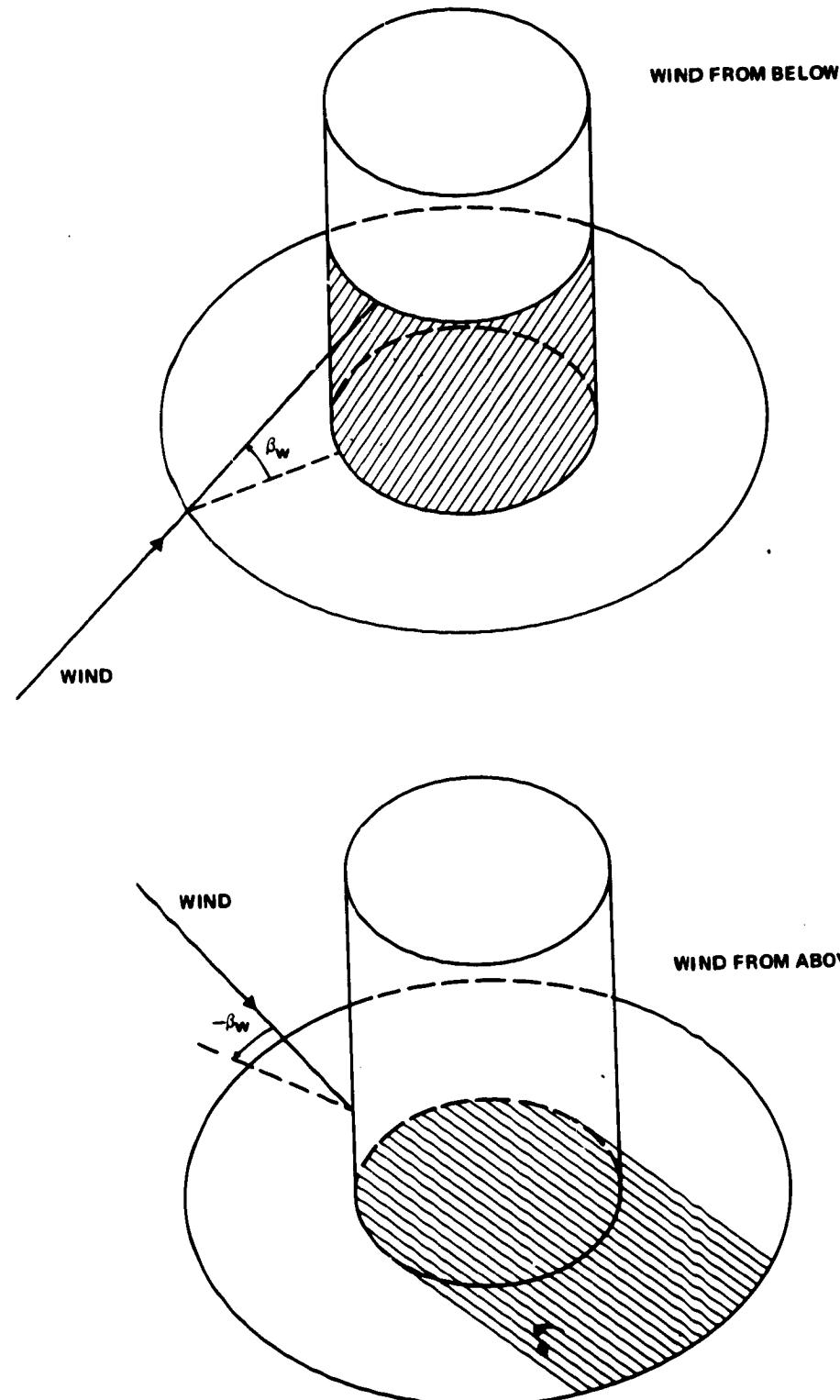


Figure 3-5. Shadows Cast by a Plate on a Cylinder (Top) and by a Cylinder on a Plate (Bottom)

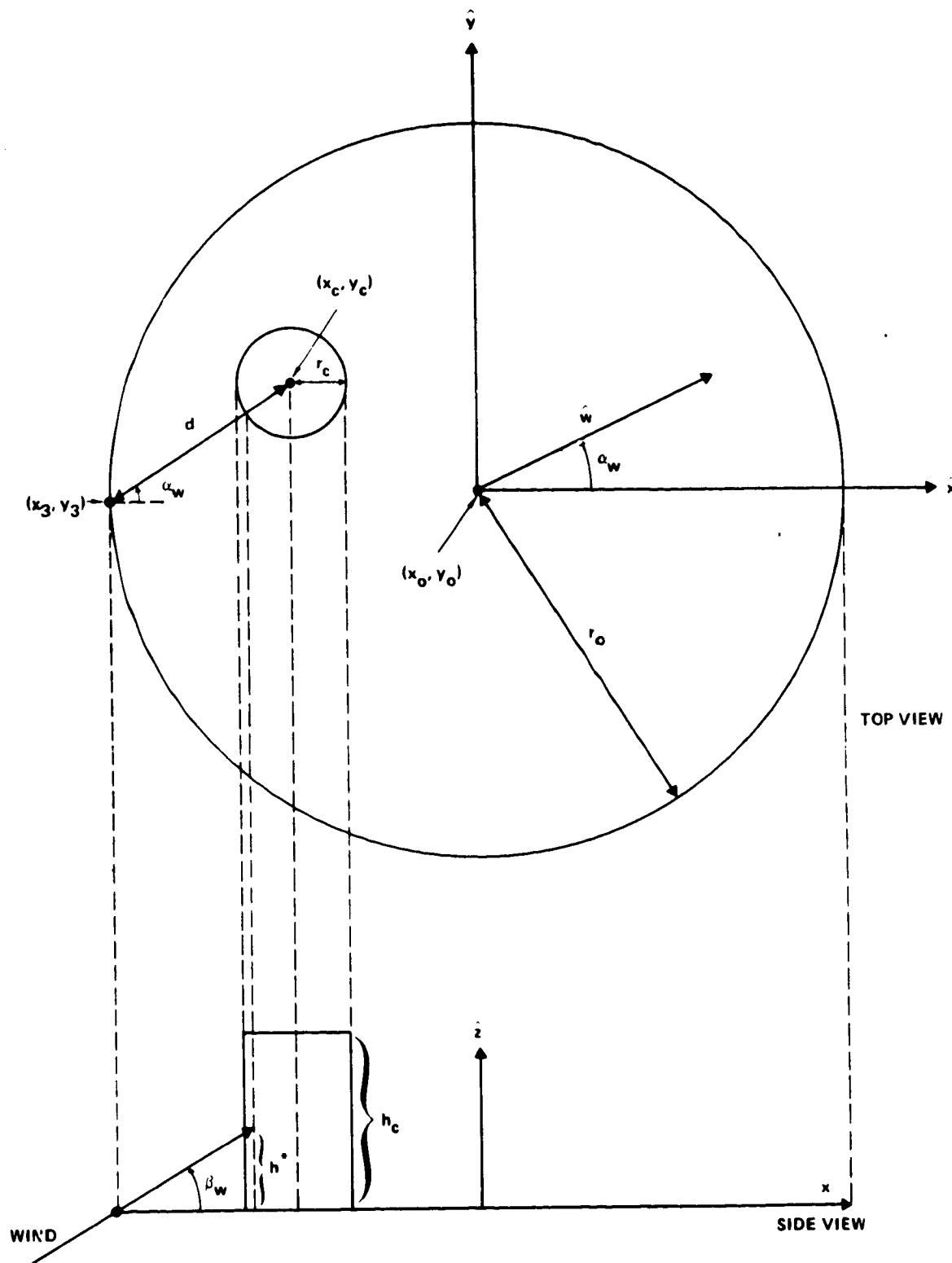


Figure 3-6. Parameters Used in Calculating Shadowing of a Cylinder by a Plate

The point (x_3, y_3) is calculated as follows. Since (x_3, y_3) is on the edge of the circular plate:

$$(x_3 - x_o)^2 + (y_3 - y_o)^2 = r_o^2$$

where r_o = radius of plate

(x_o, y_o, z_o) = center of plate in spacecraft geometric frame

Also

$$\tan \alpha_w = (y_3 - y_c) / (x_3 - x_c)$$

so

$$y_3 = (x_3 - x_c) \tan \alpha_w + y_c$$

Substitution into the circle equation gives

$$x_3^2 (1 + \tan^2 \alpha_w) + x_3 [-2x_o + 2 \tan \alpha_w (y_c - y_o - x_c \tan \alpha_w)] + \left[x_o^2 - r_o^2 + (y_c - y_o - x_c \tan \alpha_w)^2 \right] = 0$$

which can be solved for x_3 . Then y_3 follows from the slope equation.

These values are then used to evaluate d and eventually h^* , provided that the entire cylinder is not shadowed, i.e.,

$$h^* < h_c$$

where h_c = height of the cylinder.

The shadowed element has the approximate area

$$A^* = -Ah^*/h_c$$

where A = area of the unshadowed element.

In addition

$$\hat{n}^* = \hat{n}_o$$

and

$$\vec{R}^* = (x_c, y_c, z_o \pm h^*/2)$$

The plus sign is used wherever the plate is below the spacecraft x , y plane, $z_o < 0.0$. A^* , \vec{R}^* , and \hat{n}^* now completely define the shadowed area.

3.1.4.2 Shadowing of Plate by Cylinder

In this case, the cylinder shadows the plate both directly and indirectly (Figure 3-7).

The direct shadowing results in a negative area:

$$A^* = -\pi r_c^2$$

where r_c = radius of the cylinder.

In addition

$$\hat{n}^* = \hat{n}_o$$

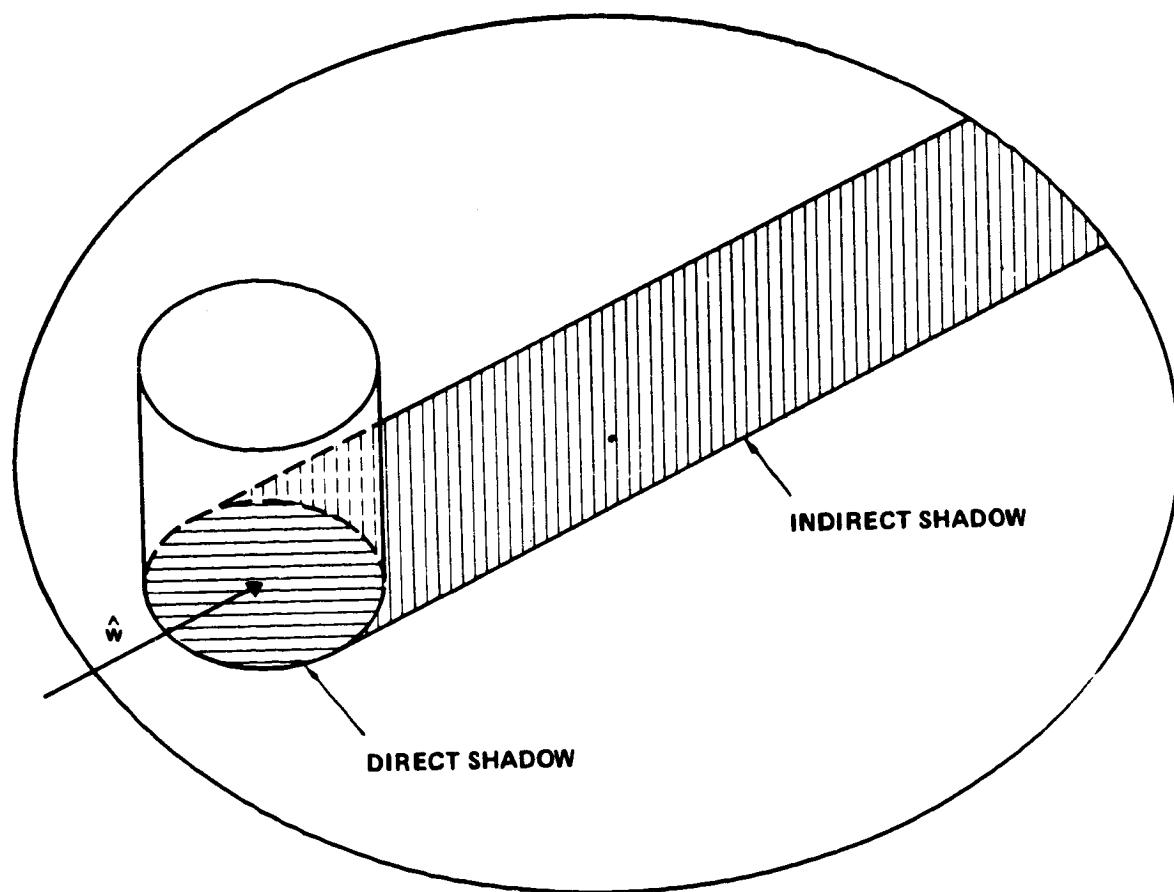


Figure 3-7. Direct and Indirect Shadows Thrown by a Cylinder on a Plate

where \hat{n}_o = unit vector normal to plate

$$\vec{R}^* = (x_c^*, y_c^*, z_o)$$

The indirect shadowing can be classified into two cases.

Case I:

In the first case, the indirect shadowing extends to the edge of the plate and is computed in the following manner. First, rotate the coordinate system to form new axes \hat{x}_N and \hat{y}_N such that \hat{y}_N points in the direction of the wind vector shown in Figure 3-8. The transformation is given by the matrix

$$M = \begin{pmatrix} \sin \alpha_w & -\cos \alpha_w \\ \cos \alpha_w & \sin \alpha_w \end{pmatrix}$$

In the new coordinate system

$$x'_o = x_o \sin \alpha_w - y_o \cos \alpha_w$$

$$y'_o = x_o \cos \alpha_w + y_o \sin \alpha_w$$

$$x'_c = x_c \sin \alpha_w - y_c \cos \alpha_w$$

$$y'_c = x_c \cos \alpha_w + y_c \sin \alpha_w$$

Figure 3-8 shows the shadow is divided into two areas, A_1^* and A_2^* .

The equation of the edge of the plate is

$$(x' - x'_o)^2 + (y' - y'_o)^2 = r_o^2$$

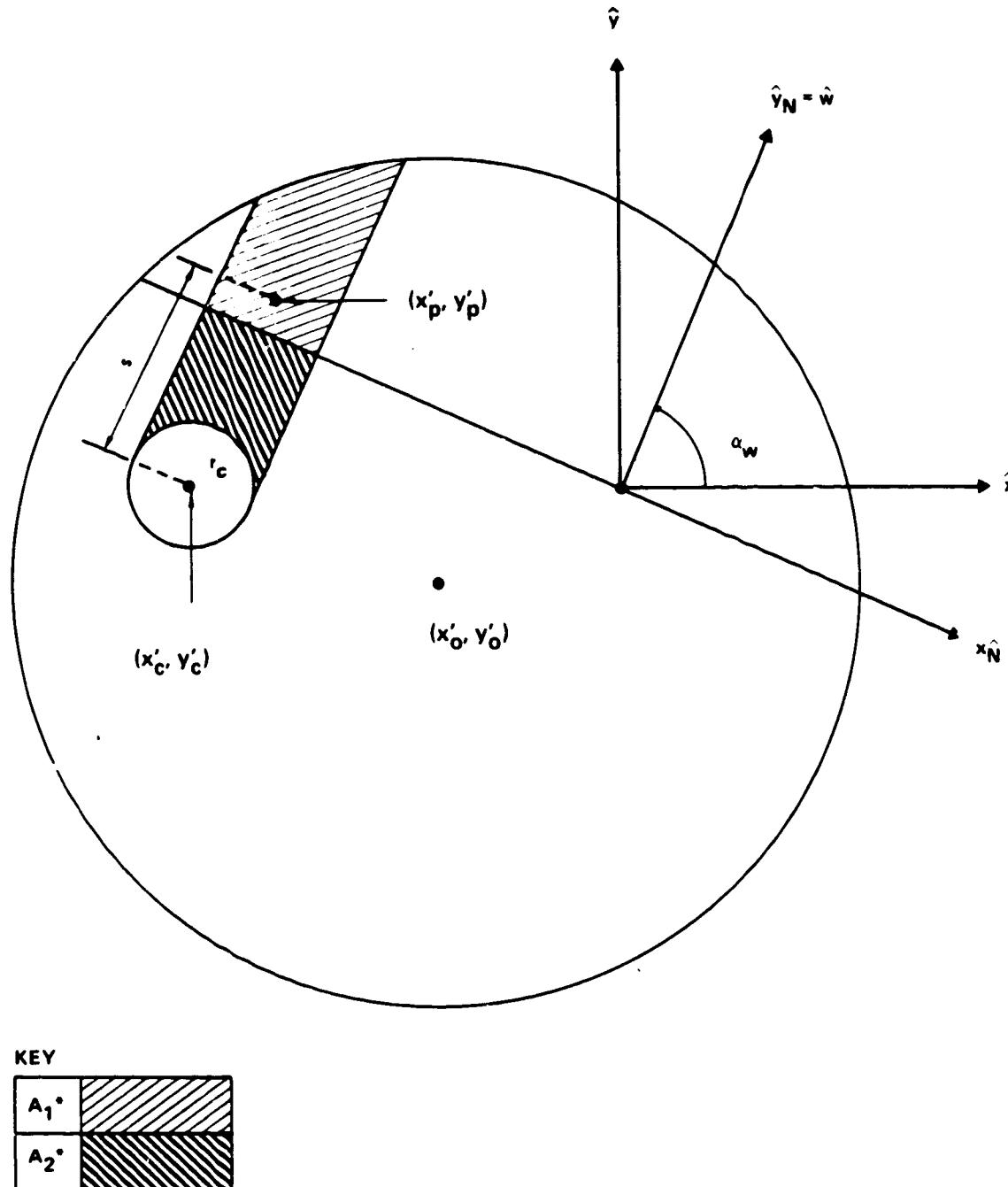


Figure 3-8. Parameters Used in Calculating Shadow Thrown by a Cylinder on a Plate

Therefore, the equation of area A_1^* can be obtained from

$$A_1^* = \int_{x'_c - r_c}^{x'_c + r_c} \left(y'_o + \sqrt{r_o^2 - (x_N - x'_o)^2} \right) dx_N$$

Evaluating this expression

$$A_1^* = \frac{r_o^2}{2} \left[\sin^{-1} \left(\frac{Q}{r_o} \right) - \sin^{-1} \left(\frac{P}{r_o} \right) + \frac{Q}{r_o} \left(r_o^2 - Q^2 \right)^{1/2} - \frac{P \left(r_o^2 - P^2 \right)^{1/2}}{r_o^2} \right] + r_c y'_o$$

$$\text{where } P = r'_c - x'_o - r_c$$

$$Q = x'_c - x'_o + r_c$$

Further,

$$A_2^* = -2 r_c y'_c - \frac{\pi r_c^2}{2}$$

and

$$A^* = -A_1^* - A_2^*$$

Let (x'_p, y'_p) shown in Figure 3-8 denote the centroid of the indirectly shadowed region, given in the rotated coordinate system. Making the approximation that the centroid lies on the shadow centerline, i.e., that $x'_p = x'_c$, y'_p is chosen so that the indirectly shadowed area between the cylinder and the point (x'_p, y'_p) is half of A^* .

This relationship can be represented by the following equation:

$$\frac{A_1^* + A_2^*}{2} = 2 r_c s - \frac{\pi r_c^2}{2}$$

Therefore

$$s = \frac{1}{4} (-A^* + \pi r_c^2) / r_c$$

and

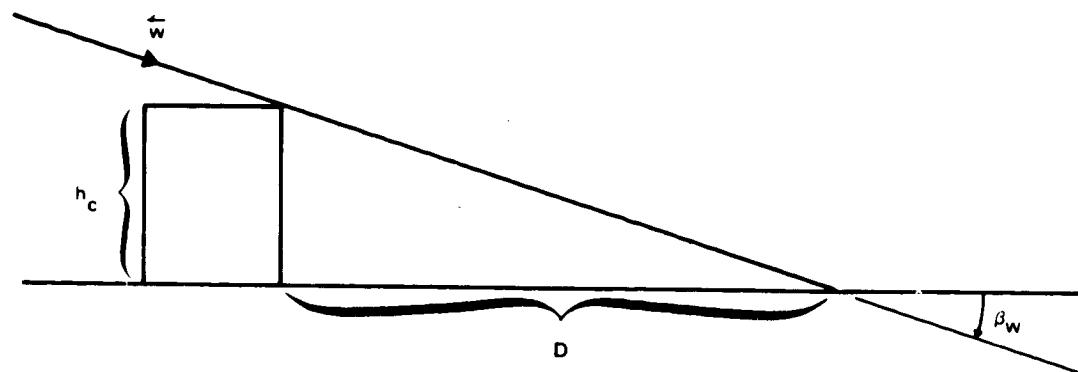
$$y'_p = y'_c + s$$

Expressed in the nonrotated coordinate system, the centroid is given by

$$\begin{pmatrix} x_p \\ y_p \end{pmatrix} = M^{-1} \begin{pmatrix} x'_p \\ y'_p \end{pmatrix} \begin{pmatrix} x_c + s \cos \alpha_w \\ y_c + s \sin \alpha_w \end{pmatrix}$$

Case II:

In the second case, the indirect shadowing does not extend to the edge of the plate, as shown below.



In this case

$$A^* = -2 r_c D$$

where

$$D = \frac{h_c}{|\tan \beta_w|}$$

In a manner analogous to that used in Case I, one can show that the centroid of this shadowed region is

$$(x_c + T \cos \alpha_w, y_c + T \sin \alpha_w, z_o)$$

where

$$T = \frac{1}{2} \left(\frac{h_c}{|\tan \beta_w|} + \frac{\pi r_c}{2} \right)$$

3.1.4.3 Summary of Shadowing Elements

The number and nature of the shadow elements created by SHADOW depends on the wind elevation angle, β_w .

Three cases can be distinguished:

1. For $\beta_w < 0^\circ$, the shadow elements are as described in Table 3-4.
2. For $\beta_w = 0^\circ$, there are shadow elements on the plates but because the wind is parallel to the shadow elements, no torques are produced. Therefore, there is no need to have shadow elements calculated.
3. For $\beta_w > 0^\circ$, the shadow elements are as described in Table 3-5.

3.1.5 Alteration of Shadowing Elements (Segment 4)

Alteration of some of the shadowing elements on the bottom plate are necessary because allowance has not yet been made for shadowing of one cylinder by another, or for overlapping of shadows thrown on the bottom plate. Figure 3-9 gives a representation of the bottom plate where the modifications are required.

3.1.5.1 Shadowing of x-Box by Mirror

Figure 3-9 defines the angles α_1 , and α_2 , which, in turn, define the fraction of the x-box shadowed by the mirror.

Calculations show: $\alpha_1 = 1^\circ$
 $\alpha_2 = 25^\circ$

Table 3-4. AE-C Shadow Elements for $\beta_w < 0^\circ$

NUMBER	TYPE	DESCRIPTION
14	0	SHADOW ON TOP PLATE CAUSED BY ADAPTER RING (DIRECT)
15	0	SHADOW ON TOP PLATE CAUSED BY ADAPTER RING (INDIRECT) ¹
16	0	SHADOW ON TOP OF ADAPTER RING CAUSED BY SPS (DIRECT)
17	0	SHADOW ON TOP OF ADAPTER RING CAUSED BY SPS (INDIRECT)
18	2	SHADOW ON MIRROR CAUSED BY BOTTOM PLATE
19	2	SHADOW ON PSB CAUSED BY BOTTOM PLATE
20	2	SHADOW ON x-BOX CAUSED BY BOTTOM PLATE

¹THE SHADOW THROWN BY THE SPS ON THE TOP PLATE IS NOT CALCULATED, SINCE IT IS COINCIDENT WITH ELEMENT 15, PROVIDED THAT $\beta_w > -3.5^\circ$.

Table 3-5. AE-C Shadow Elements for $\beta_w > 0^\circ$

NUMBER	TYPE	DESCRIPTION
14	0	SHADOW ON BOTTOM PLATE CAUSED BY MIRROR (DIRECT)
15	0	SHADOW ON BOTTOM PLATE CAUSED BY MIRROR (INDIRECT)
16	0	SHADOW ON BOTTOM PLATE CAUSED BY PSB (DIRECT)
17	0	SHADOW ON BOTTOM PLATE CAUSED BY PSB (INDIRECT)
18	0	SHADOW ON BOTTOM PLATE CAUSED BY x-BOT (DIRECT)
19	0	SHADOW ON BOTTOM PLATE CAUSED BY x-BOX (INDIRECT)
20	2	SHADOW ON ADAPTER RING CAUSED BY TOP PLATE
21	2	SHADOW ON SPS CAUSED BY ADAPTER RING ¹

¹THE SHADOW THROWN ON THE SPS BY THE TOP PLATE IS NOT CALCULATED, SINCE IT IS COINCIDENT WITH ELEMENT 21.

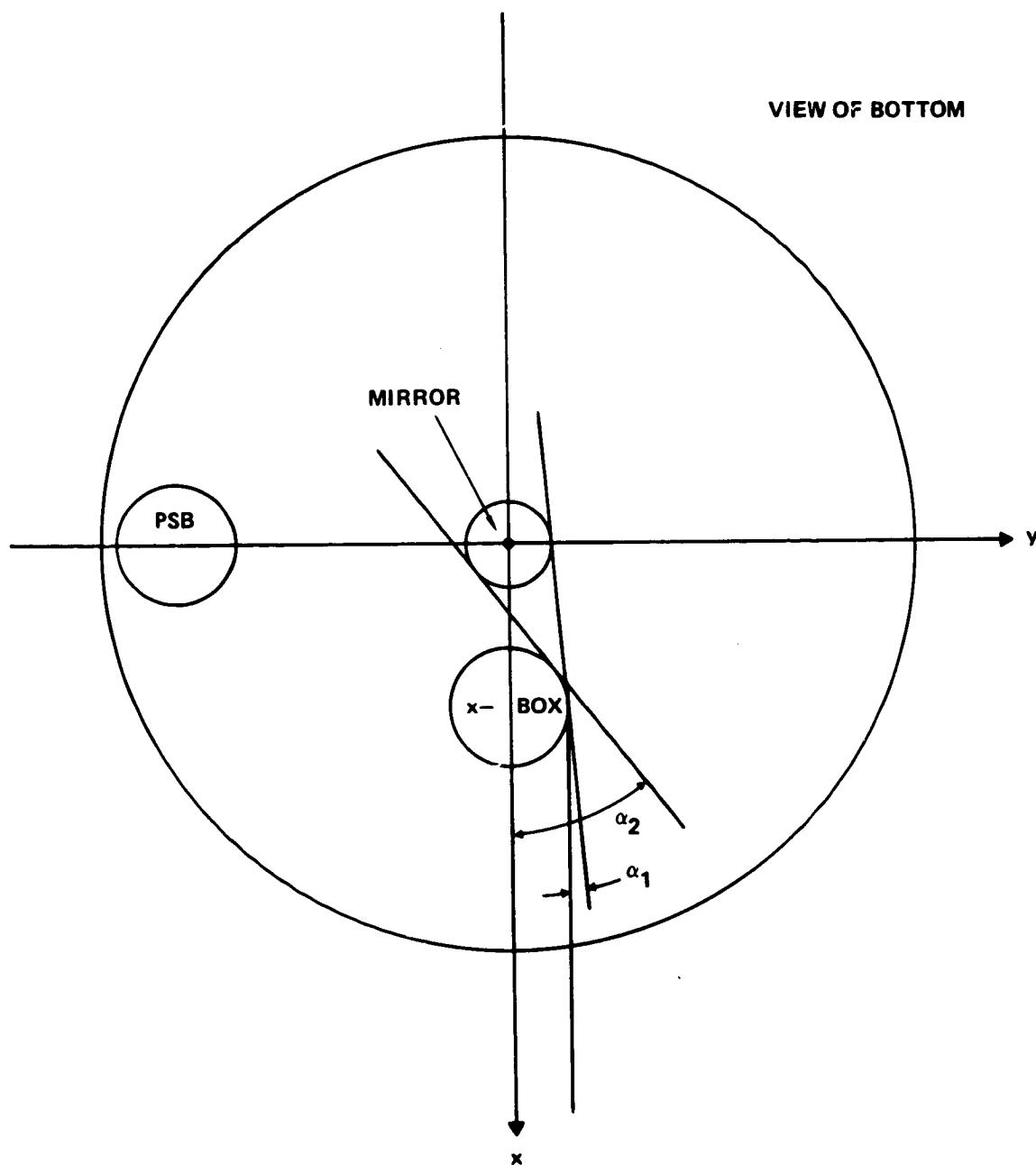


Figure 3-9. Angles Used in Calculating Shadowing
of x-Box by Mirror

The fraction of the x-box shadowed is

$$f = \begin{cases} 1 & , \text{ for } 0^\circ \leq \alpha_w < 1^\circ \text{ and } 359^\circ < \alpha_w < 360^\circ \\ \frac{25 - \alpha_w}{24} & , \text{ for } 1^\circ < \alpha_w < 25^\circ \\ \frac{\alpha_w - 335}{24} & , \text{ for } 335^\circ \leq \alpha_w \leq 359^\circ \\ 0 & , \text{ otherwise} \end{cases}$$

The shadow is assumed to cover the x-box from top to bottom, because the mirror is much taller than the x-box, and the wind elevation angles are always assumed to be small, $\beta_w < 3.5^\circ$.

The mirror is shadowed by the x-box in a similar manner for $155^\circ \leq \alpha_w \leq 205^\circ$. The approximation has been made that this can be treated identically to the above case; that is, always reducing the area of the x-box and its shadows by the factor f . It has been assumed that there is no shift in the element centroid.

3.1.5.2 Shadowing of Mirror by PSB

Figure 3-10 defines the relevant angles, α_3 and α_4 . The shadow on the mirror caused by the PSB is assumed to extend across the entire width of the mirror for

$$\alpha_3 \leq \alpha_w \leq \alpha_4$$

and is neglected otherwise. This is a valid approximation since the shadows only occur in spinning mode and sweep across the mirror quickly. In despun mode, α_w is normally outside of the range (α_3, α_4) .

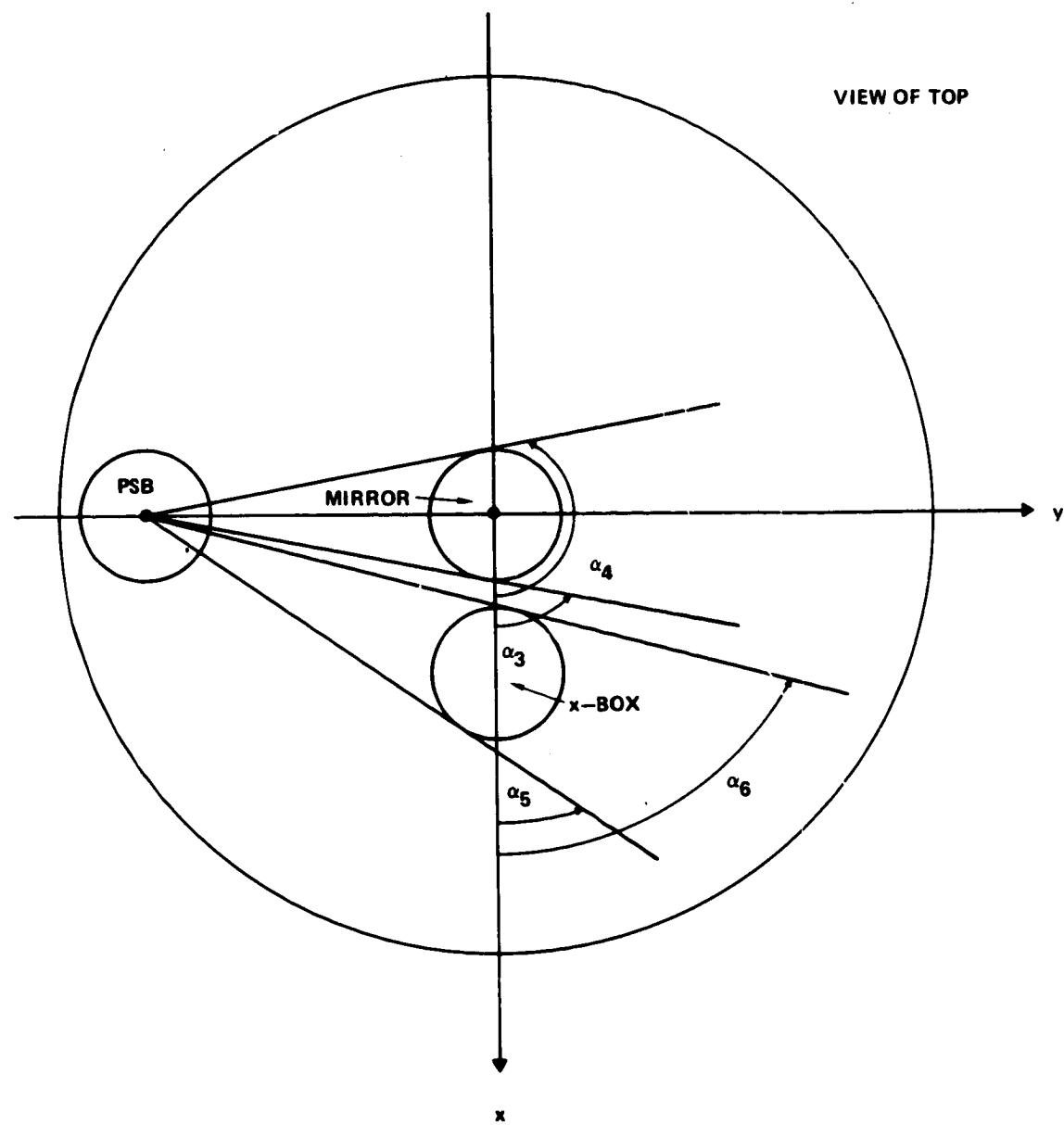
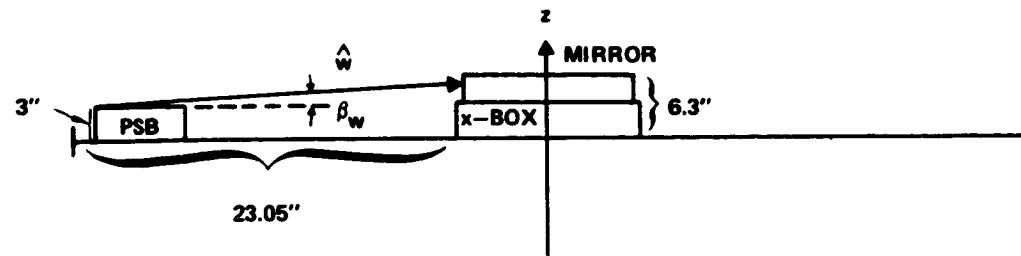


Figure 3-10. Angles Used in Calculating Shadows Thrown by PSB on Mirror and x-Box and Vice-Versa

The height to which the shadow rises is calculated from

$$h^* = 3.0 + 23.05 \tan \beta_w$$

The area of the mirror is then reduced by the fraction which is shadowed

$$A_{\text{shadowed}} = A_{\text{original}} \cdot F$$

where $F = (6.3 - h^*)/6.3$

The z coordinate of the mirror's \vec{R} vector is also altered to

$$(R_z)_{\text{shadowed}} = (R_z)_{\text{original}} + 3.15 h^*/6.3$$

The areas shadowed by the mirror during this range of α_w , if any, are set to zero to prevent double counting, as the PSB also shadows these areas.

Calculations yield: $\alpha_3 = 84^\circ$
 $\alpha_4 = 96^\circ$

3.1.5.3 Other Shadows

Similar techniques are used for the shadowing of the PSB by the mirror ($264^\circ \leq \alpha_w \leq 276^\circ$), shadowing of the x-box by the PSB ($55^\circ \leq \alpha_w \leq 70^\circ$) shown in Figure 3-10 when $\alpha_5 \leq \alpha_w \leq \alpha_6$, and shadowing of the PSB by the x-box ($235^\circ \leq \alpha_w \leq 250^\circ$).

3.1.6 Calculation of Cylindrical Offsets (Segment 5)

The wind applies a force to the cylindrical surface on that half of the surface exposed to the wind. In Figure 3-11, for example, the average moment arm has a zero y component, but a nonzero x component. Since cylindrical

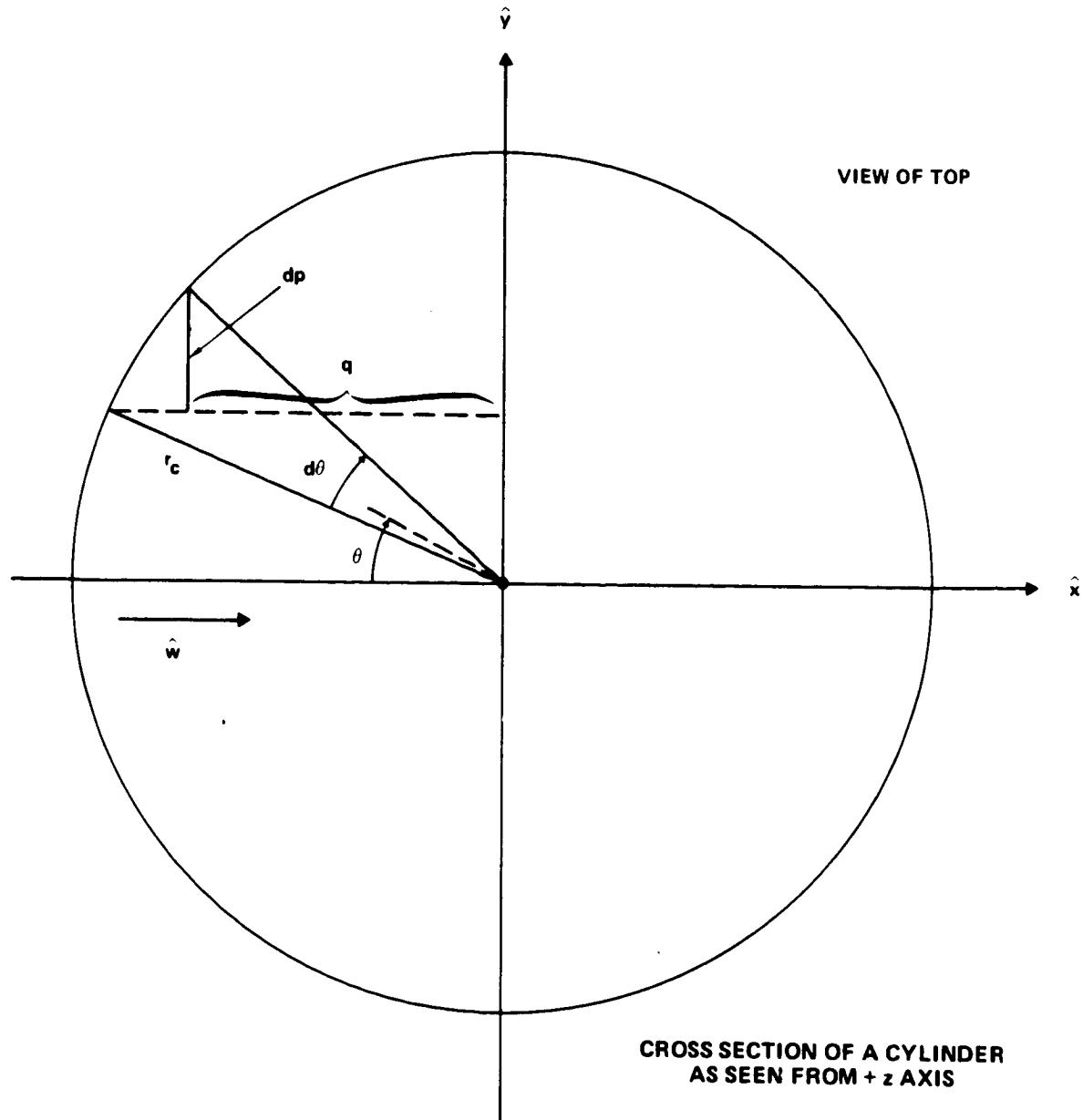


Figure 3-11. Parameters Used in Calculating Cylindrical Effects

elements assume \vec{R} is a vector to the geometric center of the cylinder, the following correction has to be made:

$$R'_x = R_x - X \cos \alpha_w$$

$$R'_y = R_y - X \sin \alpha_w$$

$$R'_z = R_z$$

where R_x , R_y , and R_z are defined by \vec{R} , and X is obtained from the integral:

$$X = \frac{\int_0^{\pi/2} q dp}{\int_0^{\pi/2} dp}$$

where $q = r_c \cos \theta$
 $dp = r_c \cos \theta d\theta$

Thus

$$X = \frac{r_c^2 \int_0^{\pi/2} \cos^2 \theta d\theta}{r_c \int_0^{\pi/2} \cos \theta d\theta}$$

$$X = \frac{\pi}{4} r_c$$

3.1.7 Output (Segment 6)

The parameters describing all the elements may be output by setting the intermediate output parameter INTOUT (100) \neq 0 .

It should be noted that PARA, PARB, and IFSHLD are meaningless for shadow elements. If the SPS is on and the spacecraft is spinning, the printout is formally correct, but, except for SPS-related elements, the torques are calculated from a formula in subroutine AEROM, and not from the elements.

3.2 SHADOW UNIT DESCRIPTION

Language

FORTRAN IV

Functional Description

Subroutine SHADOW computes negative area shadow elements subsequently used by AEROM in evaluating aerodynamic torques. The AE-C model includes satellite-dependent and -independent code, and considers the main cylinder, the adapter ring and SPS mounted on the top of the main cylinder, and the mirror, PSB, and CEP box attached to the top of the main cylinder.

Calling Sequence

Subroutine SHADOW is entered through the following FORTRAN statement:

```
CALL SHADOW (ALPHA, BETA, SUNAZI, SUNELF, IYFLAG, IDUMPX)
```

The arguments in the calling sequence are listed below:

Argument

Name	Symbol	I/O	Definition	Units	Format	Dimension
ALPHA	α_w	I	Wind azimuth angle	Radians	R *4	1
BETA	β_w	I	Wind elevation angle	Radians	R *4	1
SUNAZI	α_s	I	Sun-wind azimuth angle	Degrees	R *4	1

<u>Argument</u>	<u>Name</u>	<u>Symbol</u>	<u>I/O</u>	<u>Definition</u>	<u>Units</u>	<u>Format</u>	<u>Dimension</u>
SUNELE	β_s	I		Sun elevation angle	Degrees	R*4	1
IYFLAG		I		Sun azimuth flag = +1, $\alpha_s \leq 180^\circ$ = -1, $\alpha_s > 180^\circ$		R*4	1
IDUMPX		I		File number for diagnostic output		R*4	1

External References

None

COMMON Variables Used by SHADOW

<u>COMMON</u>	<u>Variable</u>	<u>I/O</u>
<u>Name</u>	<u>Name</u>	
AEROBD	IFC	I
	NCOMPS	I/O
	AREA(30)	I/O
	RV(3, 30)	I/O
	ANV(3, 30)	I/O
	PARA(30)	I/O
	PARB(30)	I/O
	IFSHLD(30)	I
	ITYPE(30)	I
INTOUT	INTOUT(100)	I
SPSFLG	ISPSON	I
	MSPFLG	I
	SUN(3)	I
	XYZCOM(3)	I
SHDSAV	SRV	I/O
	NCMPSV	I/O

Method

See Section 3.1.

NAMELIST Inputs

None

Other Input/Output Information

Subroutine SHADOW can produce diagnostic printout if INTOUT(100) \neq 0. Any other value yields a list of the elements, including shadow elements, and their characteristics.

Constraints, Error Conditions, and Recovery

The wind elevation angle, β_w , should satisfy the equation

$$|\beta_w| < 3.5^\circ$$

APPENDIX - LISTINGS OF SUBROUTINES AEROM AND SHADOW

This Appendix contains cross-referenced listings of the improved AEROM and the new SHADOW subroutines.

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OF POOR QUALITY

```

ISN 0026          **** CALL TABLE (HGT) ****      00007907
ISN 0027          INUMPXEDUMP      00038000
C ****
C HERE WE CALCULATE THE SUN AND WIND ANGLES.
C WF .. WIND ELEVATION ANGLE (RADIANS)      00038100
C WA .. WIND AZIMUTH ANGLE (RADIANS)        00038200
C WLEV .. WIND ELEVATION ANGLE (DEGREES)     00038300
C WAZI .. WIND AZIMUTH ANGLE (DEGREES)       00038400
C PHI .. ANGLES BETWEEN THE SUN VECTOR AND X-AXIS REFERRED      00038500
C TO SPACECRAFT XY PLANE                      00038600
C SUNAZI .. AZIMUTH ANGLE BETWEEN SUN AND WIND VECTORS      00038700
C (CALCULATED IN RADIANS, CONVERTED TO DEGREES)      00038800
C SUNLE .. ELEVATION ANGLE OF SUN VECTOR ABOVE SPACECRAFT      00038900
C XY PLANE (CALCULATED IN RADIANS, CONVERTED TO DEGREES)      00039000
C NOTE THAT SUNAZI IS CONVERTED INTO AN ANGLE BETWEEN 0 AND      00039100
C 90 DEGREES FOR THE PURPOSE OF INPUT TO A FORMULA IN
C SUBROUTINE SHADOW
C TYLEAG .. SHADOW FLAG
C =1 IF SUNAZI IS ORIGINALLY COMPUTED TO BE LESS THAN      00039200
C 180 DEGREES
C =-1 OTHERWISE
C TYLEAG IS USED IN A FORMULA FOUND IN SUBROUTINE SHADOW      00039300
C ****
C WEARED(WIND(3))      00039400
C WAFAWTH2(WIND(2),XWIND(1))      00039500
C IF(WA(.EQ.0)) WAFAWTH2=0      00039600
C WLEV=PI/2      00039700
C WAZI=TWOPI      00039800
C C(SWEPC(SINE))
C PHFATAN2(SUNP(1),SUNP(1))      00039900
C IF(PHFATAN2(.GT.0)) PHFATAN2=PI      00040000
C SUNAZI=PHFATAN2      00040100
C IF(SUNAZI.LT.0) SUNAZI=SUNAZI+PI      00040200
C TYLEAG=-1      00040300
C IF(SUNAZI.GT.PI) TYLEAG=-1      00040400
C PI32=PI/180PI      00040500
C IF(SUNAZI.GT.PI32) SUNAZI=PI-SUNAZI      00040600
C IF(SUNAZI.GT.PI32) SUNAZI=PI-SUNAZI      00040700
C IF(SUNAZI.GT.PI32) SUNAZI=PI-SUNAZI      00040800
C SUNELF=PI/2*SIN(CUCL(3))      00040900
C SUNAZI=PI/2*SIN(CUCL(3))      00041000
C SUNELF=PI/2*SIN(CUCL(3))      00041100
C ****
C HERE WE SET UP PARAMETER I AND PUT IN DIAGNOSTIC OUTPUT
C OF PARAMETERS USED IN THE TORQUE CALCULATIONS      00041200
C ****
C 00041300
C DECDF=VMAG*VMAG/2.0*16.39      00041400
C DF=(INTOUT(200)-500,2) WRITE(10UMP,200) HGT,PHC,VMAG,Q,DF,INP,TD      00041500
C 200 FORMAT(1X,1F12.5,1F12.5)
C 1      ,      PHC = 1.5125,
C 2      ,      VMAG = 1.5125,
C 3      ,      Q = 1.5125,
C 4      ,      WIND = 1.3(112.E-1),
C 5      ,      DRAG COEFFICIENT = 1.5E-3//)
C 6      ,      TQDQF(1) = 0.0
C TQDQF(2) = 0.0
C TQDQF(3) = 0.0
C ****
C IF THE SPACECRAFT IS SPINNING WE ENTER THIS LOOP AND      00041700
C CALCULATE ATROTORQUES, EXCEPT FOR THE SDS ELEMENTS.      00041800
C FF2M THE FOLLOWING FORMULAS.      00041900
C NOTE THAT WLEV IS IN DEGREES AND ZREF IS IN INCHES.      00042000
C AT THIS POINT, TQDQF HAS THE DIMENSION OF CUBIC INCHES.      00042100
C ****
C 00042200
C IF(TQDQF(1)=0.0) G1=10.902      00042300
C TQDQF(1)=0.0
C TQDQF(2)=(-4.3E-10.9E-0)*WLEV**2-2525.0*ZREF      00042400
C TQDQF(3)=0.0
C ****
C IF THE SDS IS OFF, WE ENTER THIS LOOP AND CALCULATE THE      00042600
C ATROTORQUES FROM THE SDS ELEMENTS FROM THE FOLLOWING      00042700
C FORMULAS.      00042800

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ORIGINAL PAGE IS
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C THE COMMENTS ABOVE CONCERNING UNITS APPLY ALSO HERE.
 C ****=
 ISN 0065 IF(ISP.SYN.EQ.1) GO TO 903
 ISN 0068 TORADD=1513.0
 ISN 0069 TORQUE=(T.0.0)*TORADD*TORADD*77.0*MELFY
 ISN 0071 TORQUE(2)=TORQUE (2)+TORADD*(1.0-0.0375*20FF)
 ISN 0072 903 CONTINUE
 C ****=
 C HERE WE CONVERT THE CALCULATED TORQUES INTO THE INSTANTANEOUS
 C BODY FRAME (THE FORMULAE WERE WRITTEN FOR AN INERTIAL
 C FRAME CENTERED ON THE SPACECRAFT).
 C NEXT WE CONVERT THESE INTO REAL TORQUES.
 C THE FACTOR OF 16.38 CONVERTS FROM CUBIC INCHES TO CUBIC
 C CENTIMETERS.
 C THE RESULTANT TORQUES ARE THEN IN CGS UNITS.
 C ****=
 ISN 0073 TORQUE(1)=TORQUE (2)*SIN(WA)
 ISN 0074 TORQUE (2)=TORQUE (2)*COS(WA)
 ISN 0075 TORQUE(3)=0.0
 ISN 0076 TORQUE (1)=TORQUE (1)*CD*RHO*VMAG**2/2.0*15.38
 ISN 0077 TORQUE (2)=TORQUE (2)*CD*RHO*VMAG**2/2.0*16.38
 ISN 0078 IF(ISP.SYN.F0.0) GO TO 999
 ISN 0080 902 CONTINUE
 C ****=
 C THE CALL TO SUBROUTINE SHADOW ADDS SHADOW ELEMENTS OF
 C NEGATIVE SIGN TO THE LIST OF SPACECRAFT DECOMPOSITION
 C ELEMENTS.
 C ****=
 ISN 0081 CALL SHDW(WA,WF,SUNAZI,SUNFL,TYFLAG,DUMPX,RV)
 C ****=
 C HERE WE CALCULATE THE TORQUE VECTOR CAUSED BY EACH ELEMENT.
 C ANGATK = THE COSINE OF THE ANGLE BETWEEN THE WIND AND
 C THE NORMAL VECTOR OF A PLATE ELEMENT, OR THE COSINE OF
 C THE ANGLE BETWEEN THE WIND AND THE AXIS OF A CYLINDRICAL
 C ELEMENT.
 C STATEMENT 300 CALCULATES THE PROJECTED AREA FOR A PLATE.
 C STATEMENT 350 CALCULATES THE PROJECTED AREA FOR A CYLINDER.
 C STATEMENT 400 CALCULATES THE PROJECTED AREA FOR A SPHERE.
 C ****=
 ISN 0082 DD 220 I=1,30
 ISN 0083 DD 220 J=1,3
 ISN 0084 220 T330(I,J)=0.0
 ISN 0085 DD 600 I=1,NCMPG
 ISN 0086 IF (ITYPE(1) .EQ. 1) GO TO 400
 ISN 0087 ANGATK=(ANV(1,I)*WIND(1)+ANV(2,I)*WIND(2)+ANV(3,I)*WIND(3))
 ISN 0088 IF (ITYPE(1) .EQ. 2) GO TO 350
 ISN 0089 IF (ANGATK .LT. 0) GO TO 300
 ISN 0090 IF (INTOUT(20) .GE. 8) WRITE(DUMP,250) I,ANGATK
 ISN 0091 ISN 0092 250 FORMAT(' ',PLATE,';I3,' DOES NOT FACE THE WIND. COSINE OF THE
 ISN 0093 IANGLE OF ATTACK = ',E12.5)
 ISN 0094 ISN 0095 250 FORMAT(' ',PLATE,';I3,' DOES NOT FACE THE WIND. COSINE OF THE
 ISN 0096 GO TO 400
 ISN 0097 300 ARAPRO*AREA(I)*ANGATK
 ISN 0098 GO TO 500
 ISN 0099 350 ARAPRO*AREA(I)*SQRT(1.0-ANGATK**2)
 ISN 0100 DD 400 400
 ISN 0101 400 ARAPRO*AREA(I)/4.0
 ISN 0102 ANGATK=1.0
 ISN 0103 500 FORCE=SQRTARPRO
 ISN 0104 IF (INTOUT(20) .GE. 8) WRITE(DUMP,525) ANGATK,ARAPRO,FORCE,
 ISN 0105 FNAME(ITYPE(1)+1)
 ISN 0106 525 FORMAT(' ',COSINE OF ANGLE OF ATTACK = ',E12.5,
 ISN 0107 1 ', PROJECTED AREA = ',E12.5,
 ISN 0108 2 ', FORCE = ',E12.5,
 ISN 0109 3 ', COMPONENT IS A ',AB1,
 ISN 0107 TORQ(I,1)=(RV(2,I)*WIND(3)-RV(3,I)*WIND(2))*FORCE
 ISN 0108 TORQ(I,2)=(RV(3,I)*WIND(1)-RV(1,I)*WIND(3))*FORCE
 ISN 0109 TORQ(I,3)=(RV(1,I)*WIND(2)-RV(2,I)*WIND(1))*FORCE
 C ****=
 C HERE WE SUM UP THE TORQUES FROM THE VARIOUS COMPONENTS.
 C IN THE SPACECRAFT IS SPINNING, ONLY THE ELEMENTS CONNECTED
 C WITH THE SPS ARE ADDED IN (PRESUMING THE SPS IS ON).
 C ALL OTHER ELEMENTS (AND THE SPS IF IT IS OFF) HAVE ALREADY

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C REEN ACCOUNTED FOR BY ELEMENTS AND CONNECTED ELEMENTS.
C
C **** ISN 0112      1F(1.F0.6) GO TO 920
C **** ISN 0114      1F(1.F0.7) GO TO 920
C **** ISN 0116      1F(1.EQ.2) AND .WELFV.GT.0.0) GO TO 920
C **** ISN 0118      1F(1.EQ.17) AND .WELV.LT.0.0) GO TO 920
C **** ISN 0120      1F(1.EQ.16) AND .WELV.LT.0.0) GO TO 920
C **** ISN 0122      GO TO 920
C **** ISN 0123      920 CNT IN IF
C **** ISN 0124      920 CNT IN IF
C **** ISN 0125      575 TORQUE(I,J)=TORQUE(I,J)+TORQUE(J,I)
C **** ISN 0126      F00 CNT IN IF
C **** ISN 0127      999 CNT IN IF
C **** ISN 0128      1F(1.INTOUT(20).GE.2) WRITE(1DUMP,700) TORQUE
C **** ISN 0129      700 FNINAT(0,0) TOTAL AERODYNAMIC TORQUE = .3(F12.5..)
C **** ISN 0130      1F(1.INTOUT(20).GE.1) WRITE(1DUMP,1100)
C **** ISN 0131      1100 FORMAT(0.0,0.0) *END OF INTERMEDIATE OUTPUT FROM SUB-CJ Y.T.C.
C **** ISN 0132      1F(1.INTOUT(20).GE.4) WRITE(1DUMP,42) AERO*42(*,*)
C **** ISN 0133      *SWEEP-ECONAZI*ESGANTIA=SPH
C **** ISN 0134      *TN20-ECONAZI*ESGANTIA=SPH
C **** ISN 0135      1F(1.INTOUT(20).GE.8) WRITE(1DUMP,7)
C **** ISN 0136      1F(1.INTOUT(20).GE.12) WRITE(1DUMP,1) TN20(1,1),TN20(1,2),
C **** ISN 0137      *TN20(1,2),1=1,NCNTRD
C **** ISN 0138      3 FN20(M,0) UNIT VECTOR = .3E14.3/. E14.3/. DPAG CN2230C
C **** ISN 0139      *EVATION AND AZIMUTH = .2E7.2/. WIND MAGNITUDE = .E14.3/. DPAG CN2230C
C **** ISN 0140      *ELEVATION = .7.3/. SUN ELEVATION AND ZIMUTH = .2E7.2/. CN227A00
C **** ISN 0141      *SPINNING FLAG (1E30) .13/. SPINNING (2E30) .13/
C **** ISN 0142      *FORMAT(.7E0) 3E13.5
C **** ISN 0143      7 FORMAT(.7E0) CAMPMENTS -- ./
C **** ISN 0144      RETURN
C
C THE RECT OF THIS SUBROUTINE HAS TO DO WITH STAGNCST IC
C NLIMIT.
C
C **** 1F(1.INTOUT(20).GE.2) WRITE(1DUMP,700) TORQUE
C **** 700 FNINAT(0,0) TOTAL AERODYNAMIC TORQUE = .3(F12.5..)
C **** 1F(1.INTOUT(20).GE.1) WRITE(1DUMP,1100)
C **** 1100 FORMAT(0.0,0.0) *END OF INTERMEDIATE OUTPUT FROM SUB-CJ Y.T.C.
C **** 1F(1.INTOUT(20).GE.4) WRITE(1DUMP,42) AERO*42(*,*)
C **** 1F(1.INTOUT(20).GE.8) WRITE(1DUMP,7)
C **** 1F(1.INTOUT(20).GE.12) WRITE(1DUMP,1) TN20(1,1),TN20(1,2),
C **** *TN20(1,2),1=1,NCNTRD
C **** 3 FN20(M,0) UNIT VECTOR = .3E14.3/. E14.3/. DPAG CN2230C
C **** *EVATION AND AZIMUTH = .2E7.2/. WIND MAGNITUDE = .E14.3/. DPAG CN2230C
C **** *ELEVATION = .7.3/. SUN ELEVATION AND ZIMUTH = .2E7.2/. CN227A00
C **** *SPINNING FLAG (1E30) .13/. SPINNING (2E30) .13/
C **** *FORMAT(.7E0) 3E13.5
C **** 7 FORMAT(.7E0) CAMPMENTS -- ./
C **** RETURN
C
C **** 000243900
C **** 00024100
C **** 00024200
C **** 00024300
C **** 00024400
C **** 00024500
C **** 00024600
C **** 00024700
C **** 00024800
C **** 00024900
C **** 00025000
C **** 00025100
C **** 00025200
C **** 00025300
C **** 00025400
C **** 00025500
C **** 00025600
C **** 00025700
C **** 00025800
C **** 00025900
C **** 00026000
C **** 00026100
C **** 00026200
C **** 00026300
C **** 00026400
C **** 00026500
C **** 00026600
C **** 00026700
C **** 00026800
C **** 00026900
C **** 00027000
C **** 00027100
C **** 00027200
C **** 00027300
C **** 00027400
C **** 00027500
C **** 00027600
C **** 00027700
C **** 00027800
C **** 00027900

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EXHIBIT D TO THE RECORDS PERFORMANCE LINE - TRAINING

	INFORMATION STATEMENTS	PERFORMANCE LINE - TRAINING
IV MBL	00000	00000
IV DRG	00000	00000
IV HND	00000	00000
IV GAF	00000	00000
IV LIS	00000	00000
IV ATT	00000	00000
IV HAN	00000	00000
IV GMN	00000	00000
IV GAT	00000	00000
IV QTL	00000	00000
IV JANG	00000	00000
IV JAPT	00000	00000
IV JNL	00000	00000
IV JW	00000	00000
IV VAND	00000	00000
IV POF	00000	00000
IV QFL	00000	00000
IV JYL	00000	00000
IV FGT	00000	00000
IV PCIM	00000	00000

FINAL
OF POOR QUALITY

*****F C R A N C O S S R E F E R E N C E T I T I N G * *

LABEL	DEFINED	REFERENCES
3	0140	0134
6	0141	0138
7	0142	0136
100	0018	001A
139	0023	0021
140	0024	0022
150	0025	0019
200	0057	0055
220	0084	0082
250	0091	0093
300	0097	0091
350	0096	0089
400	0101	0086
500	0103	0098
525	0106	0104
575	0125	0124
600	0126	0085
700	0135	0128
902	0080	0061
903	0072	0066
920	0125	0110
999	0127	0078
1100	0133	0131

/ AEROM / SIZE OF PROGRAM O1114 HEXADECIMAL BYTES									
NAME	TAG	TYPE	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE
NAME 1 SF	J	SF	J	SF	SF	03458	NAME 60	60	VPC
BT	C	RF4	CD	F	RF4	00000	BT	00000	AUDR
P1	F	RF4	N.F.	RF4	RF4	01044	BT	00000	RF4
PW	C	RF4	N.P.	RF4	RF4	00000	BT	00000	RF4
ANV F	C	RF4	OC1E0	DTR	C	RF4	NAME	NAME	RF4
DMI SF	C	RF4	00040C	R40	F	RF4	NAME	NAME	RF4
GUN SF	C	RF4	000C08	AREA F	C	RF4	NAME	NAME	RF4
PARA	C	RF4	N.P.	PARA	C	RF4	NAME	NAME	RF4
DRAX	C	RF4	N.D.	SLAT	C	RF4	NAME	NAME	RF4
WAZI SF	C	RF4	ORCA	WIND FA	C	RF4	NAME	NAME	RF4
COSINE S	C	RF4	00047C	DRAGB	C	RF4	NAME	NAME	RF4
RCGND F	C	RF4	000000	THROT	C	RF4	NAME	NAME	RF4
REGIN	C	RF4	N.3	RPMS	C	RF4	NAME	NAME	RF4
TABLE SF	X	RF4	000000	TEMP1	F	RF4	NAME	NAME	RF4
VTPD	X	RF4	N.W.	WELFV SF	C	RF4	000018	VELCN	RF4
COS	C	RF4	000000	WELFV SF	X	RF4	000004	VELCN	RF4
ABALD SF	C	RF4	000000	4 TAN2	C	RF4	000000	APSN	RF4
10SPDN F	CE	RF4	000004	SEFIELD	C	RF4	000000	HALFPI	RF4
IMKARD	C	RF4	000002	10UMDX SF	C	RF4	000000	TEPM	RF4
10SPDN F	E	RF4	000000	INTDU	C	RF4	000000	PRINT	RF4
MCOPNS F	C	RF4	000000	INTDU	C	RF4	000000	PRINT	RF4
SHADWN SF	X	RF4	000004	MECHAN	C	RF4	NAME	RADIUS	RF4
SUNART C	RF4	RF4	000000	CLIMAN	C	RF4	NAME	SIGNAT	RF4
TORADD SF	C	RF4	000000	SUNA ZT SF	C	RF4	NAME	SUNELF CFA	RF4
XZCDM CE	RF4	OC440	000000	TORQUE SF	X	RF4	000000	VGINFL C	RF4
***** COMMON INFORMATION *****									
NAME 1F COMMON BLOCK #AEP0930		SIZE OF BLOCK	000530	HEXADECIMAL BYTES					
VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME
VAR. IFC	RF4	N.F.	NC005	RTD	RF4	NAME	NAME	NAME	NAME
AVN	RF4	RF4	PARA	NAME	NAME	NAME	NAME	NAME	NAME
1TSPDN	RF4	RF4	CODES	NAME	NAME	NAME	NAME	NAME	NAME
NAME OF COMMON BLOCK * SP SF/G* SIZE OF ALCK 000020 HEXADECIMAL BYTES									
VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME
VAR. DTP	RF4	N.F.	4SPFLD	NAME	NAME	NAME	NAME	NAME	NAME
1TSPDN	RF4	RF4	DATA00	NAME	NAME	NAME	NAME	NAME	NAME
EQUAL VALUE VAR'S WITHIN THIS COMMON BLOCK									
WEIGHT	RF4	RF4	000004	NAME	NAME	NAME	NAME	NAME	NAME
NAME OF COMMON BLOCK * GAERT * SIZE OF BLOCK 000018 HEXADECIMAL BYTES									
VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME
VAR. P00	RF4	N.P.	SIGMAN	NAME	NAME	NAME	NAME	NAME	NAME
WEIGHT	RF4	RF4	NAME	NAME	NAME	NAME	NAME	NAME	NAME
NAME OF COMMON BLOCK * DSNS* SIZE OF BLCK 000020 HEXADECIMAL BYTES									
VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME
VAR. DTP	RF4	N.F.	INCARD	NAME	NAME	NAME	NAME	NAME	NAME
1DINK	RF4	RF4	DATA00	NAME	NAME	NAME	NAME	NAME	NAME
1DINK	RF4	RF4	NAME	NAME	NAME	NAME	NAME	NAME	NAME
NAME OF COMMON BLOCK * INTUT* SIZE OF BLOCK 000190 HEXADECIMAL BYTES									
VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME	TYPE	REL. ADDR.	VAR. NAME
CD	RF4	000C00	INTUT	NAME	NAME	NAME	NAME	NAME	NAME

LABEL	ADDR	LABEL	ADDR	LABEL	ADDR	LABEL	ADDR
130	00C92E	150	0005A2	973	000C14	902	A1CAF
220	00CC1E	3C3	300RA8	350	000DCA	ACC	220FA
500	CACE0E	920	00DF26	575	000F48	ACC	320FE
999	00FF7C						

***** IN EFFECT ***** NAME= MAIN.CPT=02111E.CPT=82.112P=000CK.

INPTIONS IN EFFECT SOURCE, EBCDIC, NCOLIST, NGNICK, LOAD, MAP, NCFEDIT, ID, XDEF

STATISTICS SOURCE STATEMENTS = 143 PROGRAM SIZE = 4456

STATISTICS NO DIAGNOSTICS GENERATED

*****END OF COMPILATION*****

128K BYTES OF CONF NOT USED

LEVEL: 21.7/1.1 (JAN 73/EGUL 74)

02/360 GRC FORTRAN H

DATE: 74-278/18-12-01

COMPILE OPTIONS - NAMES: MAIN, OPT=2, LINFCNT=82, LSIZE=600K,
 SOURCE, FPCDIC, NOLIST, NODECK, LOAD, MAF, NOECD, ID, XREF

 SUBROUTINE SHADOW CALCULATES NEGATIVE AREA SHADING
 ELEMENTS SHADED BY SUBROUTINE REPORT THE CALCULATING
 AERODYNAMIC TORQUES.
 AUTHOR *** DAVID M. GOTTLIEB, COMPUTER SCIENCE CORP.
 VERSION *** JULY 1, 1974

 SUBROUTINE SHADOW(ALPHA, RETA, SUNAZI, SUNELF, TYLEAG, IDUMPK, PV)
 COMMON /INTOUT/ INTOUT(100)
 DATA B100, I100, ITYPE(3)
 COMMON /SPSELG/ SPSELG(SUNELF, SUN(3), XYZCOM(3))
 COMMON /HOSAV/ SRVNL, MPV, SAPL1, SAR8, SRV8, SAPL11, SRV10
 EQUIVALENCE (XOFF, XYZCOM(1)), (YOFF, XYZCOM(2)), (ZOFF, XYZCOM(3))
 EQUIVALENCE (IPRINT, INTOUT(10))

 CALLING SEQUENCE VARIABLES
 ALPHA ... WIND AZIMUTH ANGLE (RADIAN)
 RETA ... WIND ELEVATION ANGLE (RADIAN)
 SUNAZI ... AZIMUTH OF WIND-SUN ANGLE (DEGREES)
 SUNELF ... ELEVATION OF WIND-SUN ANGLE (DEGREES)
 TYLEAG ... SUN AZIMUTH FLAG -
 -1 IF SUNAZI LESS THAN 180 DEGREES
 IDUMPK ... FILE NUMBER FOR DIAGNOSTIC OUTPUT
 (EV(1),EV(2),EV(3),EV(4)) ... THE VECTOR FROM THE S/C
 CENTER OF MASS TO THE GEOMETRIC CENTER OF THE ITH
 ELEMENT
 COMMON/INTOUT/ VARIABLES
 IIP ... INITIAL CALL FLAG -
 -1 IF THE FIRST TIME SHADOW IS CALLED
 NCMPLE ... NUMBER OF ELEMENTS IN THE S/C DECOMPOSITION
 AREA(I) ... SURFACE AREA OF THE ITH ELEMENT IF IT IS A
 PLATE OR A SPHERE, OR HEIGHT X DIAMETER OF THE ITH
 ELEMENT IF IT IS A CYLINDER
 RHO ... SAME AS RV, BUT CONTAINS ORIGINAL VALUES
 (ANV(1,1),ANV(2,1),ANV(3,1)) ... UNIT VECTOR NORMAL TO
 THE ITH ELEMENT IF IT IS A PLATE OR ALONG THE AXIS OF
 THE ITH ELEMENT IF IT IS A CYLINDER
 RAD(I) ... RADIUS OF THE ITH ELEMENT
 RPLT(I) ... HEIGHT OF THE ITH ELEMENT IF IT IS A
 CYLINDER
 TSHD(I) ... SHADING FLAG FOR THE ITH ELEMENT -
 -1 IF ELEMENT NEVER SHADDED
 -2 IF ELEMENT SHADDED WHEN WIND IS FROM BELOW
 -3 IF +0 (PLATE ONLY) - PLATE SHADDED BY CYLINDER
 -4 IF +0 (CYLINDER ONLY) - CYLINDER SHADDED BY PLATE
 ITYPE(I) ... TYPE OF ITH ELEMENT -
 -1: PLATE
 -2: SPHERE
 -3: CYLINDER
 COMMON/INTOUT/ VARIABLES
 INTOUT(100) ... CONTAINS THE DIAGNOSTIC OUTPUT FOR
 SHADOW -
 -1: NO DIAGNOSTIC OUTPUT
 -2: OUTPUTS ELEMENTS AND PARAMETERS DEFINING THEM
 COMMON/SPSELG/ VARIABLES
 ISPLG ... GPS CUTOFF FLAG
 -1: ON
 -2: OFF
 -3: SPIN
 -4: DESPIN
 ANY POSITIVE VALUE: SPINNING
 (SUN(1), SUN(2), SUN(3)) ... SUN VECTOR IN B.G. COORDINATES
 (XYZCOM(1), XYZCOM(2), XYZCOM(3)) ... VECTOR FROM THE S/C
 GEOMETRIC CENTER TO THE CENTER OF MASS
 COMMON/HOSAV/ IS USED TO SAVE INTERNAL VARIABLES NEEDED
 BY REPEATED CALLS TO SHADOW
 NOTE/ UNITS ARE AS FOLLOWS -
 AREA IS IN SQUARE INCHES

02004100
 02004200
 02004300
 02004400
 02004500
 02004600
 02004700
 02004800
 02004900
 02005000
 02005100
 02005200
 02005300
 02005400
 02005500
 02005600
 02005700
 02005800
 02005900
 02006000
 02006100
 02006200
 02006300
 02006400
 02006500
 02006600
 02006700
 02006800
 02006900
 02007000
 02007100
 02007200
 02007300
 02007400
 02007500
 02007600
 02007700
 02007800


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C- 0.1E 1E4 ABS(SAL-45.0)-0.04*ABS(SBE-SAL)          00011900
D+5.5E20 SIN(90F/E7.29F)                           00016000
ZV(3,6)=24.0E2.8075-0.324645PAR                   00016100
A=0.008668 SAL+0.002285AL*PAR-ZOFF               00016200
XYOFF=C.9729-0.06717#PAR                           00016300
A=0.61119E-12.27417#SAL+30.0)                     00016400
B=0.254CF-CF*(SAL-45.0)**2                         00016500
C=0.001056 ABS(SPC-SAL)+8.9840E-05*(SBE-SAL)**2   00016600
XYOFF=XYOFF*FLDAT(1,VFLAG)                         00016700
PARB(6)=ZV(3,6)-24.0E2.8075                         00016800
PARA(6)=AF(A(6))*C.5/PAPR(6)                      00016900
ZV(1,6)=SIN(ALPHA)*XYOFF-XOFF                     00017000
ZV(2,6)=COS(ALPHA)*XYOFF-YOFF                     00017100
GT TO 500                                         00017200
*****                                                 00017300
C THE NEXT SIX STATEMENTS ARE EXECUTED ONLY WHEN THE SPS IS
C DIFF.
C HERE WE ASSIGN AVERAGE VALUES TO THE PARAMETERS DESCRIBING
C SPS.
C ****
501 AF(A(1)=448.00                                00017400
ZV(1,6)=XOFF                                     00017500
ZV(2,6)=YOFF                                     00017600
ZV(3,6)=26.0-C7OFF                               00017700
PARA(6)=6.00                                      00017800
PARB(6)=4.00                                      00017900
C ****
C HERE WE DEFINE THE PARAMETERS DESCRIBING THE TOP OF THE SPS
C (ELEMENT 7).
C ****
200 CINTLUE
ZV(1,7)=ZV(1,6)
ZV(2,7)=ZV(2,6)
ZV(3,7)=ZV(3,6)+PAPR(6)-ZOFF
NAME=CINTLUE
C ****
C HERE WE RESET TO THEIR ORIGINAL VALUES SOME OF THE PARAMETERS
C WHICH WERE ALTERED DURING PREVIOUS CALLS TO SHADOW.
C ****
AF(A(1)=60013
AF(A(2)=SAF11
C ****
SEGMENT C
THIS SEGMENT CONTAINS THE SATELLITE INDEPENDENT CODE WHICH
CALCULATES SHADOW BY CYLINDERS ON PLATES AND VICE-VERSA.
EACH OF THE ORIGINAL 13 COMPONENTS IS CHECKED AND IF IT FAILS
THEW UPON IT IS CALCULATED.
C ****
07 207 T=1,NCMPR
IF(LSHLD(I1,L1,100) GT TC 207
IF(LSHLD(I1,L1,200) GT TC 208
C ****
C HERE WE CALCULATE THE SHADOW THROWN ON A PLATE BY A CYLINDER.
C THE PLATE IS ELEMENT NUMBER 1.
C THE CYLINDER IS ELEMENT NUMBER I1,L1.
C IT'S EQUALS THE PRODUCT OF THE WIND ELEVATION ANGLE AND THE
C Z COMPONENT OF THE I1TH ELEMENT'S UNIT NORMAL VECTOR. WHEN
C TEST IS POSITIVE, THERE IS NO SHADOW THROWN BY THE CYLINDER
C BECAUSE THE WIND IS COMING FROM THE WRONG DIRECTION.
C THE SHADOW IS COMPUTED AS A PAIR OF ELEMENTS -
C THE FIRST IS THE DIRECT SHADOW, DEFINED AS THAT PORTION OF
C THE PLATE PHYSICALLY COVERED BY THE CYLINDER.
C THE SECOND IS THE INDIRECT SHADOW ACTUALLY THROWN BY THE
C CYLINDER.
C ****
IL1=L1,IFSHLD(I1,L1,100
TEST=45.0*ANAL(311)
IF(TEST.GE.0.0) GT TO 207
701 CONTINUE

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C **** WE CALCULATE THE PARAMETERS DESCRIBING THE DIRECT SHADOW.
C THE PARAMETERS ARE STORED IN ELEMENT NUMBER N.
C ****
C ITYPE(N)=0
C AREA(N)=3.1415926*(LITL)
C ANV1,N)=ANV(1,1)
C ANV2,N)=ANV(2,1)
C ANV3,N)=ANV(3,1)
C SV(1,N)=SV(1,LITL)
C SV(2,N)=SV(2,LITL)
C SV(3,N)=SV(3,LITL)
C N=N+1
C **** WE CALCULATE THE PARAMETERS DESCRIBING THE INDIRECT
C SHADOW THROWN BY THE CYLINDER ON THE PLATE.
C THE PARAMETERS ARE STORED IN ELEMENT NUMBER N.
C DEFINITIONS OF VARIABLES -
C XC=VC .. THE CENTER OF THE BOTTOM PLANE OF THE CYLINDER
C R=RC .. THE RADIUS OF THE CYLINDER
C X0,Y0 .. THE CENTER OF THE PLATE
C R1 .. THE RADIUS OF THE PLATE
C AREAMX .. THE AREA SHADOWED IF THE SHADOW EXTENDS ALL
C THE WAY TO THE EDGE OF THE PLATE
C AREAAT .. THE AREA ACTUALLY SHADOWED BY THE CYLINDER IF
C THE PLATE WERE INFINITELY LARGE
C AREAEN .. THE AREA OF THE SHADOW THROWN BY THE REAL
C CYLINDER ON THE REAL PLATE = MINIMUM OF AREAMX, AREAAT
C H .. HEIGHT OF THE CYLINDER
C OTHER VARIABLES ARE USED FOR CALCULATIONS ONLY AND HAVE
C NO SIMPLE PHYSICAL MEANING.
C NOTE THAT THE CENTER OF THE SHADOW IS ALSO CALCULATED AND
C IS ADDED TO THE RV VECTOR OF FOR THE CYLINDER PERIOD BEING
C STORED IN THE RV VECTOR OF THE SHADOW.
C ****
C XC=VC(1,[LITL])
C YC=VC(2,[LITL])
C ZC=VC(3,[LITL])
C X0=VC(1,1)
C Y0=VC(2,1)
C Z0=VC(3,1)
C R=PCAP(1,[LITL])
C R=PCAP(1)
C SIN45=SIN(ALPHA)
C COS45=COS(ALPHA)
C XCB=XC*INA-YC*COSA
C YCB=XC*SINA-YC*COSA
C ZCB=XC*SINA-YC*COSA
C YCB=XC*CD6A+YC*SINA
C XCXP=XC-PC
C YCXP=YC-PC
C ZCXP=ZC-PC
C A1=4*PI*(A/R0)
C PI=4*SIN(A/R0)
C SINB=SIN(B/RC)
C A1=AM(XC+YC*ZC*2*(R1-A)+R1*RC*(R0*#2-B*#2)/R0*#2-
C 1A*RC*(R0*#2-A*#2)/R0*#2)+2.*RC*(YC-B-YCB)-0.*F3*3.141593*RC*#2
C INFATNP(LT,1,OF,-5) GO TO 600
C A-FEAT=2.0*PC*PCAPB([LITL]) ATNB
C /AREAFN=MIN1(AREAMX,AREAAT)
C HCAPB(1,[LITL])
C DB=(HC/ATNB)-1.5768*PI*#9*#5
C COMPCM=ATNB-D
C PV(1,N)=XC+COMPCM*COSA
C PV(2,N)=YC+COMPCM*SINA
C PV(3,N)=ZC+COMPCM*SINA
C AFEA(N)=AREAFN
C IF(AFEA(N)=AREAFN) GO TO 220
C PV(3,N)=YC+RC*SINA
C PV(2,N)=YC+RC*SINA
C PV(1,N)=XC+RC*COSA
C R=0.25*(AREAMX+3.1415926*#2)*RC
C PV(1,N)=XC+RC*COSA
C PV(2,N)=YC+RC*SINA
C PV(3,N)=ZC+RC*SINA
C 220 CONTINUE
C ANV1,N)=ANV(1,1)
C ANV2,N)=ANV(2,1)
C ANV3,N)=ANV(3,1)
C ITYPE(N)=0
C VM=N-1
C ****

```

ISN C 139

NEN+1

C SINCE IF SHLD ONLY ALLOWS EACH ELEMENT TO BE SHADOWED BY ONE
C OTHER ELEMENT, AND SINCE THE BOTTOM PLATE IS SHADOWED BY
C THE X PLATE, X PLX AND PSX, SPECIAL CODING IS INTRODUCED
C HERE TO ALLOW ALL THREE TO SHADOW THE BOTTOM PLATE.
C OVERLAPPING SHADOWS ARE ALLOWED FOR BELOW IN SEGMENT C.

IFC(LINE,3) GO TO 207
IFC(LINE,40,12) GO TO 207
IFC(LINE,40,13) GO TO 200
T1 TPL 12
G TO 721
700 PLTLE=10
G TO 721
20H CONTINUE

HERE WE CALCULATE THE SHADOW THROWN BY A PLATE INTO A
CYLINDER. THE ELEMENT NUMBER IS,
THE PLATE IS ELEMENT NUMBER 1 MAIN,
THE SHAD IS ELEMENT NUMBER N.
DIST = EQUALS THE PRODUCT OF THE WIND ELEVATION AND THE
UNIT VECTR ALONG THE CYLINDER AXES. IF DIST IS NEGATIVE,
THE SHADOWS ARE CALCULATED AS THE WIND IS COMING FROM THE
WEING DIRECTION.
THE DISTANCE DIST IS THE POSITIONS IN THIS SECTION ARE THE
SAME AS THOSE USED IN THE CODING ABOVE FOR THE SHADOWING
OF A CYLINDER ONTO A PLATE.
SHDRL IS THE HEIGHT TO WHICH THE SHADOW RISES ON THE
CYLINDER.
NOTE THAT FALFA FOR THE SHADOW IS CALCULATED AS THIS IS THE
RADIIUS OF THE SHADOW ELEMENT (= THE RADIUS OF THE
CYLINDER).

TESTANGANV(1,1)
IFC(TESTANG(1,1)) GO TO 207
MAIN IF SHLD(1)=200
IFC(TANALG(1,1)) TANALG(1,1)
IFC(TANALG(-1,1)) TANALG=-1,0E1
AEL=0,TPLN=0
XC=EV(1,1)
YC=EV(2,1)
ZC=EV(3,1)
XDE=EV(1,1MAIN)
YDE=EV(2,1MAIN)
ZDE=EV(3,1)
RE=2.09*XC+2.09*TANALG*(YC-YD-TANALG*XC)
EPAL=1,0A1N)
CX=RE*2.09*2*(YC-YD-TANALG*XC)*2
YADE=0.97*(H00.9-0.0A00)
TEC(LARS(ALPHA),LT,1,570E-6) RAD=E-RAD
TEC(LARS(ALPHA),LT,6,712E-6) RAD=E-RAD
X1=3E(-0.00001)/2.09*2
Y1=3E(TANALG(XN-XC)+YC)
DISTED=T((XN-XC)**2+(YN-YC)**2)
DCEPAL=1
DISTED=IST-RC
H-TAR=DISTED*TAR
ALFALG=0.9*FAL(1)*HSTAR/HG
TEC(LARS(ALPHA),LT,1,570E-6)
TYPE(N)=2
ANV(1,N)=ANV(1,1)
ANV(2,N)=ANV(2,1)
ANV(3,N)=ANV(3,1)
RV(1,N)=RV(1,1)
RV(2,N)=RV(2,1)
RV(3,N)=RV(3,1)-0.5*RAD
IF((RV(3,N)=LT,0,0)) RV(3,N)=RV(3,N)*HSTAR
IFC(HSTAR,LT,0,0) GO TO 1227
RV(3,N)=RV(3,1)-0.5*RAD
IFC(RV(3,N)=LT,0,0) RV(3,N)=RV(3,N)*HGC
1207 CONTINUE
20A END 1207
NEN+1
207 CONTINUE
ALP(F1,6)

C *****
 C THIS SEGMENT ALTERS THE SHADOW ELEMENTS AS A FUNCTION OF
 C SPACECRAFT STATUS PARAMETER D.
 C SPECIFICALLY, IT TAKES INTO ACCOUNT SHADOWING OF ELEMENTS
 C ON THE BOTTOM OF THE SPACECRAFT BY EACH OTHER.
 C THERE ARE THREE ELEMENTS ON THE BOTTOM PLATE -
 C THE MIRROR, LOCATED ON THE Z AXIS,
 C THE X-BOX, LOCATED IN THE +X AXIS, AND
 C THE PSB, LOCATED ON THE +Y AXIS.
 C WE DEFINE EIGHT ANGLES WITHIN WHICH ONE ELEMENT WILL
 C SHADOW ANOTHER.
 C THE MIRROR WILL SHADOW THE X-BOX BETWEEN 0.0 DEGREES AND
 C 180.0 DEGREES, AND BETWEEN ALP1 AND ALP2 PARTIALLY.
 C THE PSB WILL SHADOW THE X-BOX BETWEEN ALP2 AND ALP3.
 C THE PSB WILL SHADOW THE MIRROR BETWEEN ALP3 AND ALP4.
 C THE REVERSE SHADOWING CYCLES BETWEEN THE STATED ANGLES
 C AND THE STATED ANGLES PLUS 180 DEGREES.
 C *****
 C *****
 IEN 0195 ALP=25.0
 IEN 0197 ALP=25.0
 IEN 0198 ALP=25.0
 IEN 0199 ALP=25.0
 IEN 0200 ALP=37.0
 C *****
 C HERE WE CONSIDER SHADOWING OF THE MIRROR BY THE X-BOX AND
 C VICE-VERSA.
 C WE MAKE THE APPROXIMATION THAT THE TWO CONDITIONS CAN BOTH
 C BE TREATED BY SHADOWING THE SHORTER ELEMENT (THE X-BOX)
 C AND LEAVING THE MIRROR UNCHANGED.
 C BETWEEN 0 DEGREES AND ALP1 (1 DEGREE), THERE IS COMPLETE
 C SHADOWING OF THE X-BOX, BETWEEN ALP1 AND ALP2 (25 DEGREES)
 C THERE IS PROPORTIONAL SHADOWING WITH THE SHADOWING FRACTION
 C DECLINING LINEARLY BETWEEN THESE TWO EXTREME.
 C THERE IS SYMMETRIC SHADOWING ON THE OTHER SIDE OF THE X-BOX,
 C AS WELL AS 180 DEGREES OUT OF PHASE.
 C ALX IS THE WIND AZIMUTH ANGLE CONVERTED TO AN EQUIVALENT
 C ANGLE BETWEEN 0.0 AND 90 DEGREES.
 C NOTE THAT THE APPROPRIATE SHADOW ELEMENTS ARE ALSO REDUCED
 C BY THE IDENTICAL FRACTION AS THE MAIN ELEMENTS.
 C *****
 IEN 0201 ALK=ALPHAS*57.296
 IEN 0202 IF(ALX.GT.-90.0) ALK=1.0; C-ALX
 IEN 0203 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0204 IF(ALX.GT.-90.0) ALK=1.0; C-ALX
 IEN 0205 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0206 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0207 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0208 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0209 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0210 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0211 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0212 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0213 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0214 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0215 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0216 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0217 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0218 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0219 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0220 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0221 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0222 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0223 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0224 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0225 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0226 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0227 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0228 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0229 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0230 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0231 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0232 IF(ALX.GT.-1.0) ALK=1.0; C-ALX
 IEN 0233 ALK=ALPHAS*57.296
 C *****
 C HERE WE TREAT SHADOWING OF THE MIRROR BY THE PSB.
 C *****
 IEN 0234 IF(ALX.LT.ALPHB*3.0E-01) GO TO 802
 IEN 0235 HGTALK=-2.36*HGTALK
 IEN 0236 IF(BETA.LT.-90.0) GO TO 803
 IEN 0237 HGTALK=2.36*HGTALK
 IEN 0238

ISN 0240
 ISN 0242
 ISN 0243
 ISN 0244
 ISN 0245
 ISN 0247
 ISN 0248
 ISN 0249
 ISN 0250
 ISN 0251
 ISN 0252
 ISN 0253
 ISN 0254
 ISN 0255
 ISN 0256
 ISN 0257
 ISN 0258
 ISN 0259

```

    IF((HGTX.GT.=6.3) GU TD 802
    AREA(E)=4*EA(9)*HGTX/6.3
    RV(3,E)= -25.65+3.15*(6.3-HGTX)/6.3
    IF((TNR.GT.=0/34.0) GU TD 802
    AREA(14)=0.0
    AREA(15)=0.0
    GU TD 802
    CNTINUE
    HGTX=3.0-HGTBLK
    IF((HGTX.LT.=0.0) GU TD 804
    AREA(E)=4*EA(B)*HGTX/6.3
    RV(3,E)= -25.65+3.15*(6.3-HGTX)/6.3
    AREA(1P)=0.0
    GU TD 802
    BSC AREA(B)=0.0
    AREA(1B)=0.0
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE X-BOX BY THE PSB.
    ****
    IF(ALGX.LT.=ALPX.DF.ALGX.GT.ALPX) GU TD 805
    HGTBLK=-22.05*TNR
    HGTX=3.0-HGTBLK
    IF((HGTX.LT.=1.5A) GU TD 806
    AREA(12)=0.0
    AREA(13)=0.0
    AREA(14)=0.0
    IF((RFA.GT.=0.0) AREA(1P)=0.0
    IF((RFA.GT.=0.0) AREA(1B)=0.0
    IF((RFA.GT.=0.0) AREA(2C)=0.0
    GU TD 805
    BSC CNTINUE
    IF((HGTX.LT.=0.0) GU TD 805
    AREA(12)=RFA(12)*HGTX/1.5A
    AREA(13)=RFA(13)*HGTX/1.5A
    AREA(14)=RFA(14)*HGTX/1.5A
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF(ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 807
    IF((RFA.LT.=0.0) GU TD 808
    AREA(1C)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 807
    HGT CNTINUE
    AREA(1D)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF((ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 809
    IF((RFA.LT.=0.0) GU TD 809
    HGTBLK=14.4+22.05*TNR
    IF((HGTX.GT.=3.0) GU TD 809
    AREA(10)=AREA(10)*HGTX/3.0
    RV(3,10)= -25.65+0.5*HGTX
    GU TD 809
    BSC CNTINUE
    HGTX=14.4+22.05*TNR
    IF((HGTX.LT.=3.0) GU TD 809
    AREA(10)=0.0
    AREA(11)=0.0
    AREA(19)=0.0
    GU TD 809
    BSC CNTINUE
    AREA(10)=AREA(10)*(3.0-HGTX)/3.0
    RV(3,10)= -25.65+0.5*(3.0-HGTX)
    AREA(19)=0.0
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE X-BOX BY THE PSB.
    ****
    IF(ALGX.LT.=ALPX.DF.ALGX.GT.ALPX) GU TD 810
    HGTBLK=-22.05*TNR
    HGTX=3.0-HGTBLK
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 810
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF(ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 811
    HGTBLK=14.4+22.05*TNR
    HGTX=14.4+22.05*TNR
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 811
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE X-BOX BY THE PSB.
    ****
    IF(ALGX.LT.=ALPX.DF.ALGX.GT.ALPX) GU TD 812
    HGTBLK=-22.05*TNR
    HGTX=3.0-HGTBLK
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 812
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF(ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 813
    HGTBLK=14.4+22.05*TNR
    HGTX=14.4+22.05*TNR
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 813
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE X-BOX BY THE PSB.
    ****
    IF(ALGX.LT.=ALPX.DF.ALGX.GT.ALPX) GU TD 814
    HGTBLK=-22.05*TNR
    HGTX=3.0-HGTBLK
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 814
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF(ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 815
    HGTBLK=14.4+22.05*TNR
    HGTX=14.4+22.05*TNR
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 815
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE X-BOX BY THE PSB.
    ****
    IF(ALGX.LT.=ALPX.DF.ALGX.GT.ALPX) GU TD 816
    HGTBLK=-22.05*TNR
    HGTX=3.0-HGTBLK
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 816
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF(ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 817
    HGTBLK=14.4+22.05*TNR
    HGTX=14.4+22.05*TNR
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 817
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE X-BOX BY THE PSB.
    ****
    IF(ALGX.LT.=ALPX.DF.ALGX.GT.ALPX) GU TD 818
    HGTBLK=-22.05*TNR
    HGTX=3.0-HGTBLK
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 818
    BSC CNTINUE
    ***** ****
    HERE WE CONSIDER SHADING OF THE PSB BY THE X-BOX.
    ****
    IF(ALGX.LT.=ALPX+180.0.GT.ALGX.GT.ALPX+180.0) GU TD 819
    HGTBLK=14.4+22.05*TNR
    HGTX=14.4+22.05*TNR
    IF((RFA.GT.=0.0) AREA(10)=0.0
    AREA(11)=0.0
    AREA(15)=0.0
    AREA(16)=0.0
    GU TD 819
    BSC CNTINUE
    ***** ****
  
```

```

***** *****
C ***** SEGMENT F *****
C IN THIS SEGMENT WE CALCULATE THE OFFSETS THAT MUST BE
C ADDED TO THE RV VECTOR FOR CYLINDRICAL COMPONENT.
C THE OFFSET, IN THE DIRECTION OF THE MAGNETIC WIND VECT., IS
C REQUIRED BECAUSE THE WIND STRIKES THE CYLINDER. ON
C THE AVERAGE, NOT ALONG ITS AXIS, BUT AT A POINT OFFSET
C FROM THE AXIS TOWARDS THE DIRECTION FROM WHICH THE WIND
C WIND IS COMING.
C *****
C      DC 410 T=1,NCPMSV
C      IFC(I)TYPE(1)=NP(2) 60 70 829
C      RVXY=0.78E-0*PARA(1),
C      RV(1,I)=RV(1,1)-RVXY*COS(ALPHA)
C      RV(2,I)=RV(2,1)-RVXY*SIN(ALPHA)
C
C      410 CONTINUE
C *****
C ***** SEGMENT F *****
C IN THIS SEGMENT WE OUTPUT VARIOUS PARAMETERS IF DIAGNOSTIC
C OUTPUT IS REQUESTED.
C IPRINT (EQUIVALENT TO INTOUT(102)) CONTROLS THE PRINTOUT.
C IF IPRINT<0 THEN IT IS NO PRINTOUT.
C OTHERWISE, OUTPUT CONSISTS OF THE ELEMENTS, WITH INPUT
C TO AND CALCULATED BY, SUBROUTINE SHADOW, AND THE VARIOUS
C WIRES OF THE FORMATION WHICH DESCRIBE THEM. SPECIFICALLY,
C PRINTED OUTPUT CONTAINS, FOR EACH ELEMENT, ITS ID#,
C ANY UNIT VECTORS, RV VECTOR, ELEMENT TYPE, AND RADIUS
C AND HEIGHT.
C THE LAST TWO ARE VALID ONLY FOR THE ORIGINAL 13 ELEMENTS.
C THE LAST IS VALID ONLY FOR CYLINDERS.
C *****
C      IFC(IOPRINT,0,0) GOTO 400
C      WRITE(*,IUMDX,200)
C      200 FORMAT(1X,"# NUMBER TYPE ANF"
C             " FOR IT IS")
C
C      1      VECT(1)
C      2      PARAMETRS(1)
C      DC 205 T=1,NM
C      W1=ITEC1(IUMDX,201) T=1,TYPE(1),APRF(1),ANV(1,1),ANV(2,1),ANV(3,1),EV
C      *(1,1),CV(2,1),EV(3,1),PARA(1),PAFR(1)
C      201 FORMAT(1A,1F15.2,F2.4,X,3F9.4,6Y,3F10.4,4X,2F10.4)
C
C      205 CONTINUE
C      400 CONTINUE
C      NCPMSV=1
C      IFC<0
C      RETURN
C      END

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*****F J R T > A N C F O S S R F F F D E N C E L I S - I N G *****

SYMBOL	INTERNAL STATEMENT NUMBERS	0025	0026	0057	C998	CC99	0164	0155	0201	0233	0324	0325
ALPHA	0002	0025	0026	0057	C998	CC99	0164	0155	0201	0233	0324	0325
AMINI	0112											
ANSIN	0106	0107										
COMP0	0115	0116	0117									
FLOAT	0053											
HOSTAR	0173	0174	0175	C163	0164	C186	C186	C192	C193	C196	C196	C196
ILITL	0078	0084	0088	C088	C088	C088	C088	C183	C183	C183	C183	C183
IMAIN	0149	0157	0158	C161	C161	C161	C161	C183	C183	C183	C183	C183
ITYPE	0003	0063	C132	C177	C177	C177	C177	C221	C221	C221	C221	C221
SAR11	2006	0015	C072									
START3	69-64	66-13	667-6									
SRV10	0006											
XVOFF	0052	0C63	C053	CC56	CC56	0057						
AREAAT	0111	0112	0120									
AREAFN	0112	0119	0122	C124	C124	C124	C124	C122	C122	C122	C122	C122
AREAMX	0108	0112	C125	C125	C125	C125	C125	C122	C122	C122	C122	C122
HGTBLK	0236	0229	C250	C250	C250	C250	C250	C262	C262	C262	C262	C262
IDJNPX	0002	0329	C332	C332	C332	C332	C332					
FFSHLD	68-9-2	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4	68-7-4
INFQUT	0004	0008										
IPRINT	0008	2227										
ISPSIN	NNNN	0045										
IVFLAG	0002	0043										
IS_PFLG	0005											
NCMPSV	0006	0012	0017	CC69	CC69	0C73	0C73	0320	0320	0320	0320	0320
NCOMPS	0003	0C12	0336									
SHA-BG	0002											
SJNAZ1	0002	0047										
SJNELE	0002	0048										
KYZCDM	0005	0007	C007	C007	C007	C007	C007					

***** P T A N C R O S S O F F F R E N C E L I S T I N G *****

DEFINER	REFERENCE	C110	C073	C074	C080	C115	C137	C147
LABEL								
200	0614	0122	0141	0141	0142	0144	0145	0147
207	0194	0232	0232	0232	0236	0240	0244	0248
208	0145	0222	0222	0222	0240	0244	0248	0255
220	0128	0256	0256	0256	0257	0257	0257	0257
250	0021	0326	0326	0326	0327	0327	0327	0327
260	0330	0330	0330	0330	0332	0332	0332	0332
261	0337	0337	0337	0337	0338	0338	0338	0338
265	0334	0334	0334	0334	0335	0335	0335	0335
400	0335	0335	0335	0335	0336	0336	0336	0336
410	0326	0326	0326	0326	0327	0327	0327	0327
600	0122	0122	0122	0122	0129	0139	0141	0141
701	0082	0249	0249	0249	0254	0257	0257	0257
801	0232	0256	0256	0256	0260	0260	0264	0264
802	0222	0256	0256	0256	0264	0264	0264	0264
803	0249	0249	0249	0249	0274	0274	0274	0274
804	0257	0281	0281	0281	0284	0284	0284	0284
805	0281	0276	0276	0276	0294	0294	0294	0294
806	0276	0276	0276	0276	0294	0294	0294	0294
807	0294	0294	0294	0294	0296	0296	0296	0296
808	0291	0291	0291	0291	0296	0296	0296	0296
809	0314	0298	0298	0298	0301	0301	0301	0301
810	0306	0298	0298	0298	0308	0308	0308	0308
811	0114	0219	0219	0219	0214	0214	0214	0214
850	0219	0220	0220	0220	0221	0221	0221	0221
851	0220	0221	0221	0221	0226	0226	0226	0226
852	0221	0221	0221	0221	0269	0269	0269	0269
900	0769	0055	0055	0055	0045	0045	0045	0045
901	0055	0191	0191	0191	0186	0186	0186	0186
1207	0191	0231	0231	0231	0227	0227	0227	0227
4603	0322	0322	0322	0322	0330	0330	0330	0330
4604	0304							

LABEL	LINE	LABEL	LINE
LABEL		LABEL	
ACDF		ACDF	
223 003CAF	2004F2	4901 20057C	007584
901 0CC7A4	2007D1	731 200846	600 C00H33
220 0009B2	700 000FA4	228 200BF2	1207 00082
207 000F92	203F9E	851 200FAA	C0FAA 801
852 0C3FF4	800 C010C5	803 2010A8	C010C8 804
802 C71234	806 C01145	805 2001FB	0C11CA 808
807 00117A	811 C0123A	811 001268	809 C01292
410 3C12F4	266 C013C4	A7C 7013A4	
OPTIONS INFFECT*	NAME= MAIN, DPT=C2, LINFCNT=A2, SIZF=0000CK.		
OPTIMS INFFECT*	STUDCE, FUNCIC, HULIC, NCDFCK, LCAD, MAP, NODIT, IR, XEFF		
STATISTICS*	STUDCP, STARTPAGE = 338, PRINTPAGE = 5272		
STATISTICS* IN DIAGNOSTICS GFNFATR0			
***** END OF COMPILATION *****			

REFERENCES

1. Computer Sciences Corporation, 3000-25800-01TR, MSAP/AE System Description, G. Carey and M. Phenneger (to be published)
2. --, 3000-25700-03TM, Summary of Changes to MSAP/AE Program to Include a Modified Shadowing Aerodynamic Torque Model and Parameter Estimation, D. Gottlieb, C. Gray, and S. Hotovy (to be published)